EX-ANTE IMPACT ASSESSMENT OF GENETICALLY MODIFIED MAIZE ADOPTION IN EL SALVADOR

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By

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Abstract

Field trial evaluation of genetically modified insect resistant (GM IR) maize provided valuable information as to the agronomic impacts of this technology on the Salvadoran maize sector. However, an economic impact assessment of the technology is absent. To provide some information in this gap of knowledge, this study undertakes an *ex-ante* economic impact assessment of GM IR maize adoption in El Salvador. Medium-term projection results show a considerable welfare gain for the overall economy, with consumers being the principal beneficiaries. Trade ramifications of adopting transgenic maize are analyzed and appropriate alternatives are explored to possible market shutdowns. This economic impact assessment could potentially compliment the environmental and social impact evaluation of GM technology in El Salvador.

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List of Abbreviations and Acronyms

BCR	Central Bank of El Salvador
CA	Central America
CAFTA-DR	The Dominican Republic-Central America FTA (With the United States)
CENTA	National Center for Agricultural and Forestry Technology
CPB	Cartagena Protocol on Biosafety
ECJ	European Court of Justice
ES	El Salvador
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Food and Agricultural Policy Research Institute
FTA	Free Trade Agreement
GM	Genetically Modified
GM IR	Genetically Modified Insect Resistant
GMO	Genetically Modified Organism
PGAI	Price Guide of Agricultural Inputs
HT	Herbicide Tolerant
IPRs	Intellectual Property Rights
LMAE	Law of the Environment of El Salvador
MAG	Ministry of Agriculture and Animal Husbandry
MARN	Ministry of the Environment and Natural Resources
MINEC	Ministry of the Economy
MT	Metric Ton (1,000 Kilograms or 2,204.62 pounds)
NPV	Net Present Value
OECD	Organization for Economic Cooperation and Development
REMSOMG	Special Rules for the Safe Handling of Genetically Modified Organisms
TRQ	Tariff Rate Quota
USD	United States Dollar

Chapter 1. Introduction

1. Introduction

Advances in biological technology in agriculture have increased crop output per unit of land. These advances have been crucial to the productivity increase of crops and have great potential to sustain that increase into the coming decades (Miflin, 2000). The effect on economic growth resulting from improved crop varieties has been observed and measured in countries such as, the United States (Griliches, 1960) and Taiwan (Hsieh and Lee, 1966). However, the implications these advances have on economic development and agricultural productivity are not well understood by social scientists, political leaders, or civil society. Though the adoption of improved crop varieties could potentially be welfare enhancing, it is not possible to generalize this notion to all varieties and all adoptees. Indeed, a case-by-case impact assessment is required in order to categorize a crop variety as beneficial or not worth adopting.

More recently, genetically modified (GM) crops, which are the result of a relatively novel innovation in biology (genetic modification), have become the center of intense debate. Many studies have documented economic benefits resulting from the adoption of these crops (Brookes and Barfoot, 2009; Marra et al., 2002; Smyth, 2014; Zilberman et al., 2007). However, the adoption of GM crops does not necessarily entail welfare enhancement. In fact, it is possible to lose from the adoption of GM crops (Gray et al., 2004). Triffid flax, the first GM crop variety to be registered in Canada is an iconic example. Although it was a crop variety that offered herbicide tolerant benefits to farmers, it was not licensed for import into Europe, which was the market for 80% of Canadian flax production at the time. To avoid the loss of this critical market, Canadian flax producers led industry action to not grow Triffid flax which ultimately ended in the deregistration of the variety (Warick, 2001). In another example, Furtan et al. (2005) found that although GM wheat met all scientific criteria for approval, producers would have lost economic surplus from the loss of export markets had that hybrid been licensed. The adoption of GM crops can also negatively impact the production and markets for non-GM crops when cross contamination occurs. Whether or not a GM crop results in welfare enhancement depends on a variety of factors.[1] Thus, it is not possible to make generalizations of the technology's effects as observed in other countries or regions.

Seven years ago, El Salvador (a developing country) undertook field trials evaluating GM insect resistant (IR) maize. Agronomic evaluation of the transgenic maize hybrids revealed potential yield increases and production costs reductions. However, the effects from wide scale adoption remain unknown. Furthermore, El Salvador also has a honey industry which exports mainly to Germany. The adoption of a GM hybrid could potentially affect this industry in some way. And although many developing countries have benefited from GM crop adoption (Areal et al., 2013; Kathage and Qaim, 2012; Qaim and Zilberman, 2003; Riesgo et al., 2012), these results cannot be generalized to El Salvador. For this reason, quantifying the economic implications the adoption of GM maize could have in El Salvador through an *ex-ante* assessment is important. This is the type of assessment this study undertakes.

1.1.1. Background of El Salvador

El Salvador is the smallest and most densely populated country in Central America (Figure 1.1). A variety of factors have been employed to explain a civil war that devastated the country, lasting from 1980 to 1992. Not least important among these factors was agrarian inequality. In analyzing the agrarian structure of El Salvador over 30 years, Seligson (1995) noted that central to agrarian inequality was the access to land. Although agrarian inequality was diminished with the land reform, urban and international migration, and a decline in birthrates that occurred after the civil war ended, the problem persisted for hundreds of thousands of Salvadorans in the post-conflict era. Land scarcity coupled with overpopulation are to remain enduring components of the Salvadoran agricultural sector for decades to come (Seligson, 1995).

Nonetheless, a tropical climate allows for the farming of a variety of crops and livestock. Monoculture is the prevalent farming system in El Salvador. Most crop production takes place in mountainous areas with gradients over 15% (Herrador and Dimas, 2000). Staples of local consumption such as beans, rice, white maize, and sorghum are all produced on small scale subsistence farms, on average 0.3-2 ha in size (Herrador and Dimas, 2000). Salvadoran rural enterprises are poorly serviced by infrastructure services and rural poverty is acute (Lanjouw, 2001).

[1] Such as market structure, consumer acceptance and policy context into which they are adopted.

Figure 1.1. El Salvador's Location in Central America

The country has a small open economy. Nine free trade agreements (FTA) are in effect with two more currently under negotiation (MINEC, 2016).[2] Among other structural elements often cited as responsible for the deterioration of the Salvadoran agricultural sector are the adoption of a *laissez-faire* agricultural price policy coupled with trade liberalization (Acevedo et al., 1995; Gingrich and Garber, 2010). The low competitiveness and profitability of Salvadoran agriculture, particularly white maize production, is due in part to poorly conceived agricultural policies and cultural constraints (Angel, 2003).

1.1.2. The Salvadoran Maize Sector

For the vast majority of Salvadoran maize farmers, maize cultivation is not a means to escape poverty; it merely provides a degree of food security at the household level. According to Rivera (2014) there are 365,680 producers of maize in El Salvador. That is, of the 370,692 total grain producers in the country, 99% are involved with maize production. Figure 1.2 shows the development in El Salvador of maize production area, total maize production, and average yields from 1996 to 2014. The area cultivated with maize has remained relatively constant over the last 19 years. Total production has steadily increased, though, not without sudden declines coinciding

[2] Ministry of the Economy of El Salvador (MINEC).

with adverse weather conditions. Although yield per hectare in El Salvador has also tended to increase over the last 19 years, overall it has remained low at an average of 2 metric tons (MT) per hectare (Ortez Andrade et al., 2014). To contextualize this yield, it is illustrative to compare it to the average maize yield of other developing countries. The average maize yield per hectare between 1996 and 2014 in Honduras was 1.5 MT, in Mexico it was 3 MT and in Argentina it was 6 MT (FAOSTAT, 2015).

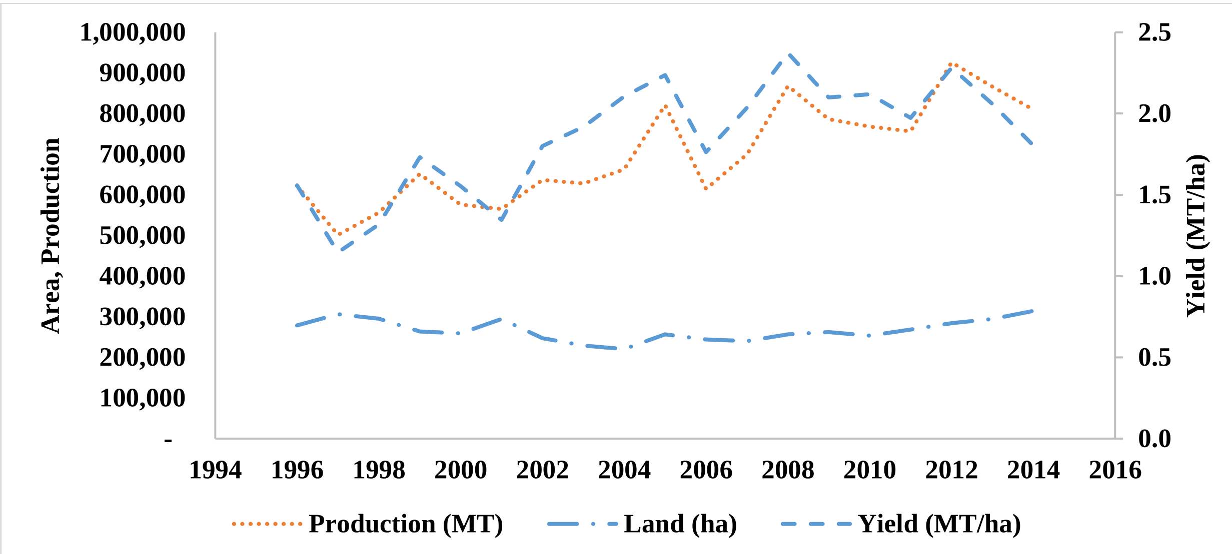

Figure 1.2. Development of Maize Production in El Salvador (1997-2014)

Source: Based on Data From (MAG, 2015)

1.1.3. Salvadoran Maize Seed Industry

Figure 1.3 depicts the Salvadoran maize seed industry. Nine percent of maize seed sown in the country are from autochthonous maize varieties and are typically cultivated in remote regions of El Salvador. This study is concerned with hybrid maize seed and the area designated to its cultivation. In 2009, 91% of total maize sown in the country was certified hybrid seed. The government supplied 52% of this hybrid seed while 39% was supplied by private agribusiness. One agribusiness firm in particular has significant market power in the Salvadoran maize seed industry. Monsanto Company acquired Marmot, S.A. which operated Semillas Cristiani Burkard in 2008 (MONSANTO, 2008). At the time of acquisition, Semillas Cristiani Burkard had operated within El Salvador for 40 years, controlling 70% of the Salvadoran hybrid maize seed market (Ferrufino, 2009). The remaining 30% was shared by Prosela with 10%, Pioneer with 8%, and El Surco and Ipexagro controlling the remaining 12% of the market (Ferrufino, 2009). With its acquisition, Monsanto now supplies 27% of the total conventional hybrid maize seed sown in El Salvador. This is an important fact because Monsanto and Pioneer are the firms that supplied the GM hybrid maize seed that Salvadoran authorities evaluated in field trials (explored in depth in Chapter 3).

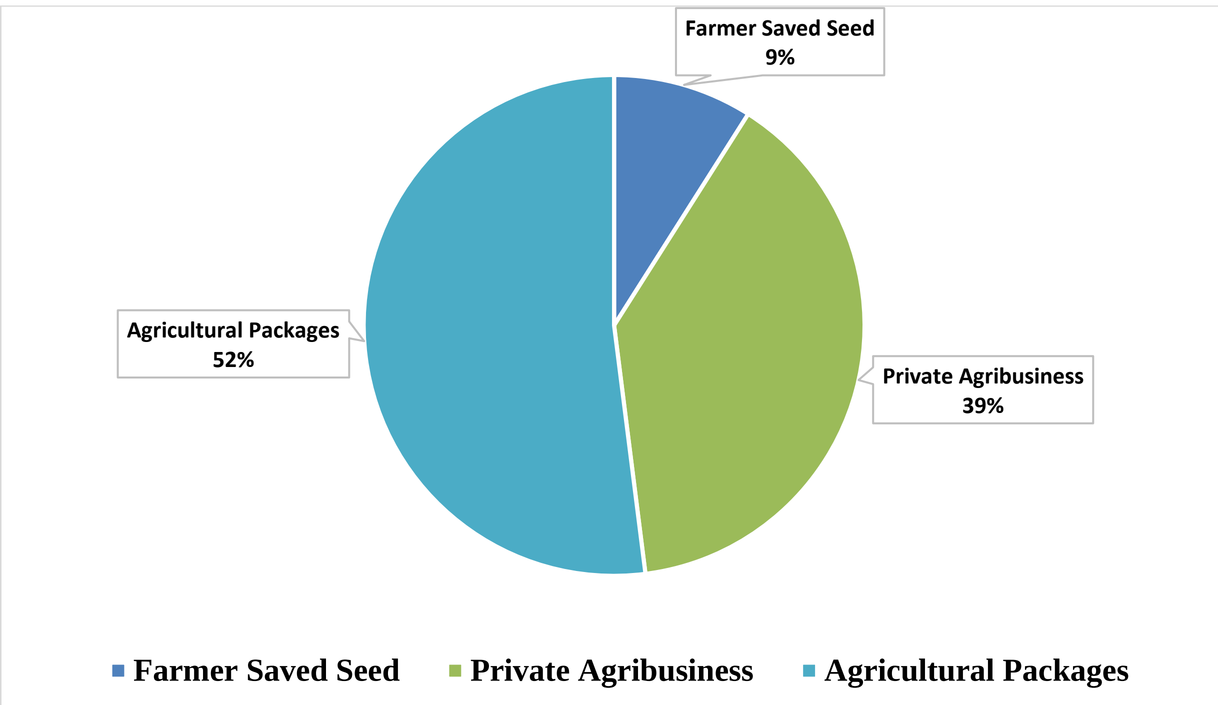

Figure 1.3. Maize Seed Industry of El Salvador

Source: Ferrufino (2009)

The government, for more than a decade through the National Center for Agricultural and Forestry Technology (CENTA) has subsidized Salvadoran maize farmers in the form of 'agricultural packages'.[3] This subsidy consists of 22 lbs. of certified hybrid seed and 100 lbs. of fertilizer (Rivera, 2014). [4] The seed is purchased from private maize seed providers. In 2013, the

[3] CENTA is the research and extension bureau of the Ministry of Agriculture and Animal Husbandry of El Salvador (MAG).

[4] The fertilizer provided to farmers is ammonium sulfate i.e. a nitrogen source.

government of El Salvador invested a total of $19.5 million to provide a total of 379,050 'agricultural packages' and distribute an equal amount of the subsidy per recipient (MAG, 2015).[5] Anyone who solicits the subsidy is eligible to receive it i.e. it does not matter if the producer is a subsistence farmer or a large producer, anyone involved in maize production qualifies for an agricultural package. Non-subsistence farmers typically solicit an agricultural package and in addition to that, purchase hybrid seed so as to increase the amount of land they cultivate.

CENTA only distributes maize hybrids through its assistance program. The most important among the maize hybrids disseminated by CENTA is the hybrid H-59. This hybrid has the genetic potential to yield up to 4.5 MT per hectare (Deras Flores, 2011). However, this genetic potential is rarely if ever achieved by Salvadoran maize farmers due to biotic and abiotic constraints. Abiotic constraints to Salvadoran maize production are beyond the scope of this study. The next section details and describes the principal pests that limit maize production in El Salvador.

1.1.4. Pest Hindrance to Maize Production in El Salvador

The amount and diversity of insect pests is far greater in the tropics than in temperate zones (Oerke et al., 1994). Three insects in particular are the perpetual plight of the Salvadoran maize farmer, namely *Spodoptera frugiperda* (fall armyworm), *Diatraea sp.* (maize stalk borer), and *Helicoverpa zea* (maize earworm). Fall armyworm damage to maize can manifest itself in three ways: (1) if the plant is recently germinated, the insect cuts the stem and proceeds to feed on the plant; (2) if the plant is fully matured, fall armyworms feed on its leaves; and (3) the insect is also known to perforate and eat into the maize ear. At any stage of development, fall army worm damages maize in El Salvador (Deras Flores, 2011). Damage from this pest has been reported to cause an 8% yield reduction in El Salvador and if left untreated, can be even greater (Andrews, 1980).

Maize stalk borer larvae also cause a considerable reduction of yield; once this pest is inside the plant stalk, spraying pesticides on the plant has no effect on the larvae inside (Deras Flores, 2011). And lastly, maize earworms almost always feed on the kernels on the top third of the

[5] El Salvador adopted the US dollar as its official currency in 2001; all prices throughout this thesis are in US dollars.

maize ear, which is an unpleasant sight for consumers and an economic loss for farmers (Hagerman, 1995). The low price of maize inhibits small-scale farmers from the use of inputs such as pesticides because it is not always a profitable option. When these inputs are used, their mismanagement by Salvadoran farmers has resulted in pest resistance problems and beneficial insect population decline (Jaco et al., 2009). Maize hybrids that provide a certain degree of pest abatement and do not require as much pesticide as conventional hybrids do would likely enhance farmer welfare.

1.2. Salvadoran Honey Industry

According to the latest agricultural census, between 2007 and 2008 there were 849 permanent jobs created in the honey industry (IV Censo Agropecuario, 2009). There are 68,902 beehives distributed among 2,050 apiaries throughout the country and in 2013 honey exports amounted to $6.1 million, up 30% from 2012 (MINEC, 2016). In 2015, of the 3 MT of honey produced, 2.3 MT were exported and of those 2 MT were exported to the Europe. If GM maize is commercially cultivated in El Salvador, undoubtedly the regulations concerning the importation of a product partly constituted with GM components (GM maize pollen) will have to be examined. This is explored in Chapter 3.

1.3.Problem Statement

In an effort to aid the Salvadoran maize farmers, at the end of 2008 and the beginning of 2009, through CENTA, Salvadoran agricultural authorities undertook field trials evaluating GM maize hybrids.[6] Two important conclusions emerged from the field trials: (1) GM insect resistant (IR) maize hybrids yielded significantly higher than their conventional counterparts and (2) the use of these hybrids does not warrant the use of pesticides.[7] The query that emerges is, economically, who would be the potential gainers and losers from the adoption of GM IR maize?

Furthermore, the technology entails externalities that need to be identified and assessed. That is, should transgenic maize hybrids be adopted, their pollen will likely be disseminated into the environment potentially having economic effects on other industries. This is a point of interest

[6] Field trials were conducted in accordance to the Cartagena Protocol on Biosafety to the Convention on Biological Diversity (CPB)

[7] Field trials are explored in depth in Chapter 3.

because El Salvador has a honey industry and the majority of exports are destined to Europe.[8] Thus, the economic effects GM IR maize could potentially have in the Salvadoran maize industry need to be juxtaposed with those it could potentially have on the honey industry. Economic analysis is undertaken in order to provide some information as to the potential effects the adoption of GM IR maize could have in El Salvador.

1.4. Objectives and Contribution

The objective of this thesis is to examine the change in welfare and the distribution effects (among relevant economic agents) from the adoption of the GM IR maize varieties evaluated by CENTA.

The specific objectives of this thesis are to:

(1) Measure and report the **change in economic surplus** from the adoption of GM IR maize evaluated in the field trials undertaken in the country.
(2) Disaggregate and determine the **distribution of this surplus** among the relevant economic agents (farmers, consumers, and the owner of the intellectual property rights to the technology). This will answer the question: who stands to gain the most from adopting GM IR maize in El Salvador?
(3) Identify the **implications for trade**, **if any**, from the adoption of GM IR maize.
(4) Determine and economically **assess any potential externalities** that may arise from adoption of GM IR maize.

1.5. Thesis Organization

A review of literature on innovation, knowledge and economic growth, biotechnology and economic approaches to its assessment is presented in Chapter 2. The methodology used in measuring and determining the distribution of economic surplus is presented in Chapter 3. Chapter 4 presents and discusses results. Chapter 5 presents a conclusion to this study.

[8] Explained further in Chapter 3.

Chapter 2. Literature Review

2. Introduction

This chapter reviews the literature on the economics of innovation, the models that conceptualize its process and the reason innovation capacity is different between developed and developing countries. An explanation of knowledge forms, mechanisms, and importance for economic growth is then provided. The transfer of knowledge is linked with an example and presented in the next section. The role knowledge plays in endogenous growth theory is presented from two different viewpoints, one emphasizing capital (Romer, 1990) and the other emphasizing accumulation of human capital (Lucas, 1988). The remaining sections focus on biotechnology, its regulation and economic evaluation.

2.1.1. Innovation

Innovation is defined by Fagerberg, Mowery and Nelson (2006) as the first attempt to carry out an invention or put an idea into practice. For Rogers (2003: p. 12) innovation is "… an idea, practice, or object perceived as new by an individual". Rogers argues that it is of little importance if an idea is objectively new, if the idea seems new to an individual, it is an innovation. In contrast, Schumpeter (1939: p. 84) defines innovation as "…the setting up of a new production function". In essence, for him, innovation is nothing but a new way of combining factors of production. For Schumpeter (1939: p. 80) "although most innovations can be traced to some conquest in the realm of either theoretical or practical knowledge, there are many which cannot". Solo (1951) disagrees with Schumpeter's distinction between invention and innovation. Solo defines invention as a change in the level of technological knowledge, and for Solo, that may as well be considered the source of innovation.

However, despite Solo's criticism of Schumpeter's view on innovation, his work is widely acknowledged and very influential. His analysis of innovation and its effect on economic development led him to regard innovation as the process responsible for determining economies. Upon this analysis, he coined the term 'creative destruction' (Schumpeter, 1950). Economic progress consists in the destruction of old paradigms and the construction of new ones. For Schumpeter, entrepreneurs are responsible for changing the existing market structure, thus, economic development depends on the actions they take. Schumpeter further details this concept by noting that an innovation can take five possible forms:

(1) It can take on the form of a new good or new quality of a good;
(2) It can take on the form of a new method of production;
(3) It can be the opening of a new market;
(4) It can involve the conquest of a new source of supply or of raw materials; and
(5) It can involve a novel way of organizing an industry. [9]

The assumption this model makes is that at first, only entrepreneurial producers introduce a new technology into a particular industry (Marks et al., 1995). In this thesis however, innovation is defined and understood in the same way as Hayami and Ruttan (1971) understood and defined it. For them, innovation embraces the entire range of processes resulting in the emergence of novelty in science, technology, industrial management and economic organization. This definition and understanding of innovation also implies that invention becomes a subset of innovation on which patents can be obtained. Defining innovation in this manner encompasses innovation more broadly, than the narrow definitions of Schumpeter (related to business activities of entrepreneurs), Solo (1951), Fagerberg et al. (2006), or Rogers (2003).

2.1.2. Conceptual Models of Innovation

Innovations have two components, an idea component (which all innovations possess) and an object component, which is something material that not all innovations possess. Early on, innovation literature advocated a rather simplistic sequence of complex activities that ultimately ended in the marketing of a product or service. Innovation in this input-output framework is preceded by a fixed and linear sequence of complex activities. Maurice Holland developed his idea of the research cycle as a precursor to what became the now seldom used linear model of innovation (Godin, 2011)(Figure 2.1).

[9] Marks, Kerr, and Klein, (1995) devised an administrative framework in anticipation of the effects of new biotechnologies by adapting Schumpeter's model of economic development. Though, they point out that while Schumpeter's model illustrates economic forces at work, it is not sufficiently detailed to provide an operational frame work for 'policy makers' and 'decision takers' to anticipate the effects of modern biotechnology.

For Holland, the prime mover of industry was research because according to him, it reduces to a minimum the period between scientific discovery and mass production. As evidence that research reduced what he called 'time-lags' he portrayed the development of industries as a series of successive stages. He termed that sequence the 'research cycle', which consisted of seven steps. For Holland the reduction to a minimum of 'time-lags' was the criterion of effectiveness of scientific research (Godin, 2011).

Research → Development → Production → Marketing

Figure 2.1. Linear Model of Innovation

While this framework has been influential and used widely by scientists to lobby for research funds as well as advise policy makers, it does have limitations. It is now recognized that innovations can assume many forms and stem from many sources, thus, the process is not completely linear. Kline and Rosenberg (1986) identified two shortcomings that to them best represented the drawbacks and limitations of the linear model:

1. It generalizes a chain of causation that only holds for a minority of innovations; and
2. The linear model ignores the many feedback loops that occur between the different stages of the process.

To address the complexity and uncertainty in the process of innovation, and the limitations the 'linear model' suffers, Kline and Rosenberg (1986) proposed an alternative model of innovation. The 'chain link' model considers five paths of activity in contrast to only one in the 'linear model' (Figure 2.2). Extending upon the 'linear model', the 'chain link model' depicts with greater accuracy the complexity of the innovation process. Feedback, is an essential part of the cooperation between the product's specification, its development, the production process, its marketing and the service components of a product line (Kline and Rosenberg, 1986).

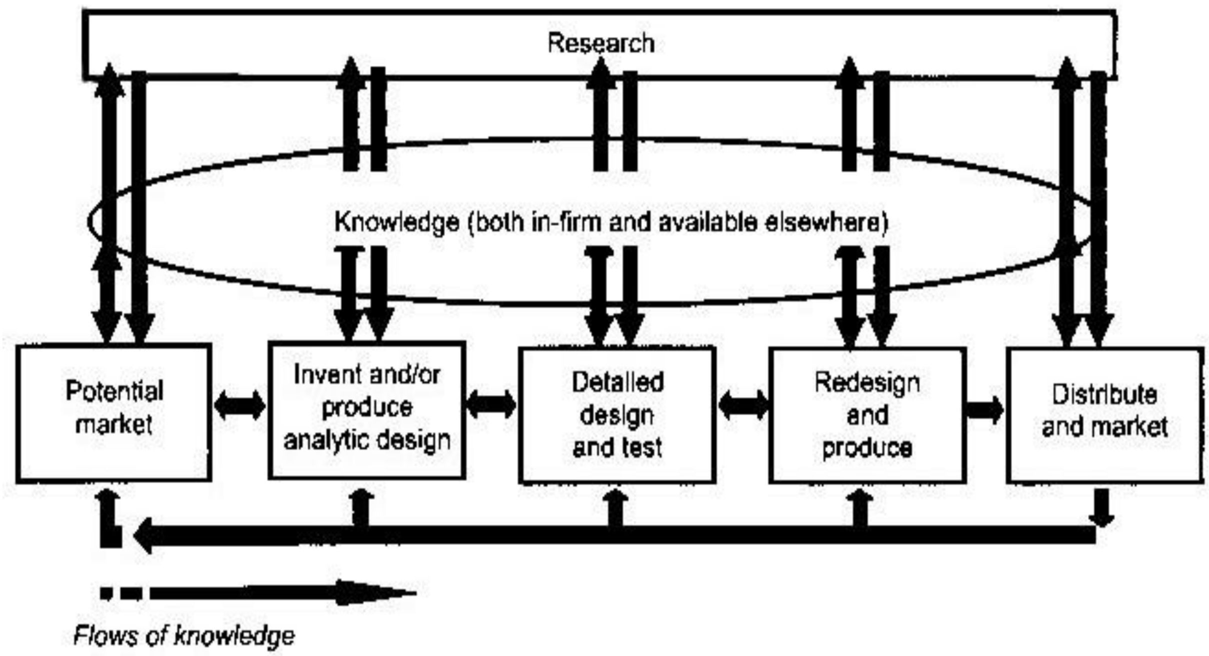

Figure 2.2. The Chain Link Model of Innovation

Source: Kline and Rosenberg (1986, p. 290)

In firms, innovation does not usually occur unless there is a perceived economic benefit to be gained from innovating. By way of illustration, in developed countries firms involved in agricultural research and development (R&D) tend to underinvest in R&D, because they are not able to capture all the benefits from their innovation. This may occur because of poor intellectual property rights (IPRs) enforcement or spillovers (Alston, 2002; Gray and Malla, 2007; Malla and Gray, 2003).[10] Thus, innovating agricultural firms usually begin by combining existing knowledge rather than creating it. In developing countries innovation is approached differently because of asymmetries in innovative capacities with respect to developed countries (Mellor, 1966; Weiss and Bonvillian, 2013). Developing countries continue to view innovation as a process of 'big-pushes' driven by R&D and investments in science-technology or industrial processes without sustained linkages to users (market-oriented) (Kaplinsky et al., 2010). It is important to note that regardless of where innovation occurs, knowledge underlies innovation and it becomes a valuable resource for sustained economic development.

[10] R&D increases the stock of knowledge, which provides a flow of services as inputs to agricultural production.

2.2. Knowledge

It is widely acknowledged that innovation is central to the growth of output and increase in productivity. Though understanding of the economic impact of innovation has increased, it is far from complete (OECD, 2005). Due to advances in technology and flows of information, knowledge is viewed as a central driver of economic growth and innovation. The term '*knowledge-based economy'* stems from that recognition. In 1996, the Organization for Economic Co-Operation and Development (OECD) published a report titled 'The Knowledge Based Economy'.[11] A discussion of trends in the knowledge-based economy, the development of knowledge-based indicators, and of statistics was undertaken. It was understood that knowledge is key to long-term economic growth, thus, understanding and incorporating knowledge and information into the standard production function is of increasing importance. [12]

Investments in knowledge can potentially increase the productive capacity of the other production factors as well as transform them into new products and processes. Since these knowledge investments are characterized by increasing (contrary to decreasing) returns, they are the key to long-term economic growth. What is poorly understood by most is the time lag separating the discovery of abstract principles (new knowledge) with their actual practical application and the fact that once they affect production, they do so for a long time (Alston et al., 1998; Romer, 1994).

However, how can an innovator seek an innovation of which he has no knowledge? Rogers (2003) argues that the innovation-decision process begins with the *knowledge function,*[13] in which an individual is exposed to the innovation and has a grasp of how it functions. To better understand and divert from the tacit or codified knowledge debate, Lundvall and Johnson (1994) proposed an elaborate set of distinctions that better classify knowledge:

[11] It was estimated that 50 per cent of gross domestic product (GDP) in the major OECD countries was knowledge-based (OECD, 1996).

[12] Not simple because it defies basic economic principles such as that of scarcity. Analytical approaches are being developed so that knowledge can be included more directly in the standard production function.

[13] The stock of knowledge cannot be observed; this is part of a conceptual apparatus rather than an empirical tool.

- Know-what;
- Know-why;
- Know-who; and
- Know-how.

These distinctions in knowledge make it easier to understand the different channels and mechanisms through which knowledge is gained. Know-what and know-why can be obtained from books, or attending lectures; know-who and know-how are related to 'hands on' experience.

The different types of knowledge have shaped two ideal type modes of learning (although, there are more) that have been the subject of debate in the 'knowledge literature' (Johnson et al., 2002). One mode is based on the production and use of codified scientific and technical knowledge; the science, technology and innovation (STI) mode. The other is an experienced-based mode of learning based on doing, using and interacting (DUI-mode) (Fitjar and Rodríguez-Pose, 2013). Empirically, Jensen et al. (2007) demonstrate that firms that employ or combine strong versions of both modes are more likely to innovate, which in turn increases their productivity.

However, knowledge is of little use if it is not translated into something economically useful, and for that to happen it must be transferred or communicated. The determinant of successful national economies and enterprises is dependent on the effectiveness of gathering and using generated knowledge (OECD, 1996). The diffusion and use of information and knowledge as well as its creation is of increasing importance in knowledge-based economies.

2.2.1. Innovation Clusters

In 2013, Canada's State of the Nation Report elaborated by the Science, Technology and Innovation Council (STIC) of Canada outlined strong and weak points in research conducted within the country. Three pillars pertaining to the STI ecosystem were measured: business innovation, knowledge development and transfer, and talent development and deployment. Although the production and refinement of scientific knowledge in Canada continues to be characterized by vitality and high quality, its miscommunication stymies economic development and societal well-being. According to the report, Canada continues to face 'chronic'[14] challenges in the transfer of knowledge developed in higher education institutions (universities or centers of innovation) to firms that have the ability to absorb it and translate it into commercially viable products or solutions to health, environmental and social problems that afflict Canadians. The report reinforces the notion that knowledge and technology increase productivity; but in order to do so, they must be transmitted or communicated. The report also establishes that 'people' are the best mechanism or channel for the transfer of knowledge.

In a knowledge-based economy the flows and relationships among industry, government and academia in the development of science and technology are an important economic determinant (Cooke, 2001; Etzkowitz and Leydesdorff, 2000). Intuitively, 'clusters' might be considered when contemplating these relationships, although these vary according to industry (Audrestsch and Feldman, 1996). Held (1996) argues that the limited definition of clusters is not sufficient to analyze them. [15] Statistical techniques alone are not sufficient to understand why clusters form or what policies are needed to foster their growth. That is why the combination of a qualitative and quantitative approach is needed. Understood in the cluster framework is that knowledge spill overs occur (Grossman and Helpman, 1996), thus productivity increases.

Cooke (2001) introduces a regional innovation system approach (RIS) that considers the linkages of clusters on a wider or global scale. He suggests that regions exhibiting high levels of economic performance have complex market-led innovation systems. He contrasts the innovation systems of the EU and the US concluding that the reason the EU innovation system lags behind its US counterpart is the absence of a proactive 'support system' behind it. [16] He also concludes that EU policy has failed to provide private innovation with a support system that allows it to take a more proactive attitude towards growth than the public system has shown itself capable of. The relationship between firms and their 'supportive structure' are responsible for fostering innovation.

Etzkowitz and Leydesdorff (2000) understand innovation to be dynamic, and so too then, must the relationships between the different actors involved in the innovation process be (Figure

[14] Page 63, (STIC, 2013).

[15] In New York, the working definition of 'clusters' is a group of related industries located in the same region.

[16] 'Soft infrastructure' is a term used to denote the enterprise support subsystem for innovation.

2.3). The ‘Triple Helix’ model is not expected to be static and more accurately describes the relationship currently being contemplated among universities, industry and governments. Generally, most developed countries are attempting to attain an innovative environment consisting of university spin-offs, tri-lateral initiatives for knowledge based economic development and strategic alliances among firms, government laboratories, and academic research groups (Etzkowitz and Leydesdorff, 2000). Through this network of relations, innovations can be defined at different levels and from different perspectives.

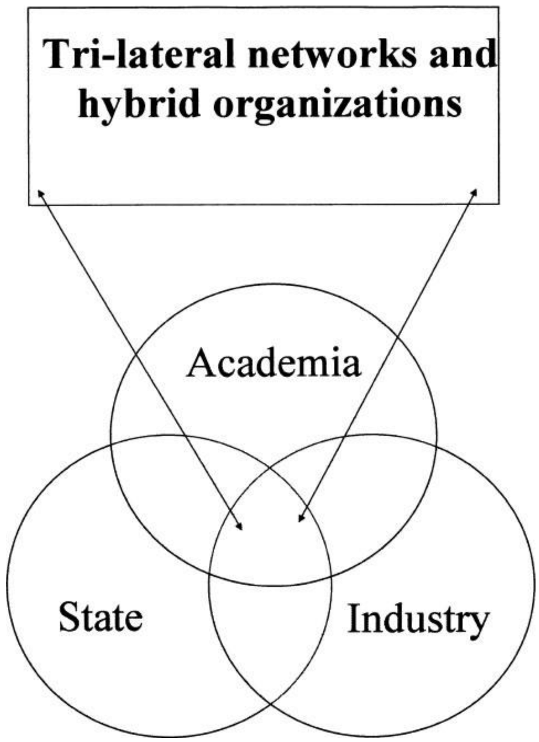

Figure 2.3. The Triple Helix Model of University–Industry–Government Relations

Source: Etzkowitz and Leydesdorff (2000, p.111).

It is increasingly becoming clear that science is the foundation of future industrial development. The generation of knowledge is imperative to economic growth and societal well-being. The challenge lies in understanding how to best transfer knowledge. The next section describes the role of knowledge in economic growth from two different points of view.

2.2.2. Endogenous Growth Theory in terms of Physical and Human Capital

Romer (1990) proposes a growth model driven by technological change in which intentional investment decisions are made by profit-maximizing agents. The model is founded on three premises that pertain to technological change.[17] The defining characteristic of technology is that developing new and improved instructions (new knowledge) are the same as incurring fixed costs. Grossman and Helpman (1994) agree that profit seeking investments in knowledge play a role in long-term economic growth, and that a growth model that does not contemplate technological change is implausible. For Hayami and Ruttan (1971) it is rational to assume that profit-maximizing agents will invest in technological change, with the aim of substituting increasingly expensive factors of production for less expensive ones. Central to Romer's contribution to growth theory is the distinction between a rival good and a purely nonrival good.[18] Nonrivalry has two important implications for growth theory:

1) Nonrival goods can be accumulated without bound on a per capita basis, and;

2) Treating knowledge as a nonrival good makes it possible to sensibly consider knowledge spillovers or non-excludability.

Basic scientific research is an example of a nonrival good that is relevant for modeling growth because it has a 'crowding' effect, rather than a 'crowd out' effect that usually occurs with private research (Gray et al., 2006). While Romer emphasizes physical capital, Lucas (1988) emphasizes human capital as an important element in endogenous growth theory. Lucas is explicit in differentiating the way human capital affects current production and the way current time allocation affects the accumulation of human capital. In an example of a closed system set forth by Lucas, all human capital accumulation is learning-by-doing. Lucas argues that knowledge is universal and that differences in technology across countries does not pertain to the stock of knowledge. Rather the difference pertains to the knowledge possessed by people or particular subgroups of people.

[17] Romer understands technological change as the improvement in the instructions for mixing together raw materials.

[18] A rival good is deemed as such when the owner can prevent others from using it. A nonrival good has the property that its use by one firm or person in no way limits its use by another.

An example that entails both perspectives on economic growth is the development of modern biotechnology. The development of a new set of techniques and processes in biology led to development of new a branch in science: molecular biology. Molecular biology is responsible for the creation of new instruments (physical capital) and the training of scientists in a novel field (human capital). Zucker et al. (1998) empirically demonstrate the connection between intellectual human capital resulting from applied research and the founding of firms in the biotechnology industry. Government funded universities were central to the development of this industry, however, entrepreneurial oriented scientists shaped the industry once it diverted from universities and government funding (Zucker et al., 1998).

2.3. Agricultural Biotechnology

Biotechnology is defined as: the use of living organisms, or products from living organisms, to benefit humans (Brooker et al., 2013). It is not a new practice. It began about 12,000 years ago when humans began to domesticate animals and plants for food production. During the 1960s, genetic engineering developed as a radical innovation of biotechnology that some expected to transform agriculture. However, "its use in food production, in particular, has provoked highly polarized reactions among producers, consumers, scientists and environmentalists worldwide" (Falkner, 2007: P. 1). In a risk perception study, Savadori et al. (2004) find that both experts and the general public perceive food applications of biotechnology to have a higher degree of risk than medical applications. Ambivalence surrounds these concerns though, as no conclusive evidence of negative human or environmental impacts from the consumption of GM food, or the release of GMOs into the environment currently exists. In fact, some studies show that GM crops pose no greater risk to the environment than do conventional crops, while others indicate they are beneficial to the environment (Brookes and Barfoot, 2010; Easac, 2013; European Commission, 2010; Huang et al., 2008; Nicolia et al., 2014; Smyth et al., 2011).

2.3.1. Genetic Modification: An Extension of the Plant Breeding Tool Box

The twenty-first century has been acknowledged as the century of plant breeding (Ortiz Rios, 2015; Stamp and Visser, 2012). Plant breeding is an important tool in increasing food production so as to keep pace with a growing and more affluent world population (Albajes et al., 2013). It can also become a powerful tool in maintaining harmony between agricultural practices necessary to satisfy those growing demands, and achieving environmental sustainability

(Brummer et al., 2011). Prior to the use of pesticides, the use of resistant crop varieties was the only method of crop protection against diseases and pests. Initially these varieties were obtained through the simple selection of plants with observable desired traits. The implementation of knowledge gained through the study of genetics led to the modern systematic approach to crop breeding.

Conventional plant breeding (CB) involves the interbreeding of closely or distantly related plants and the concomitant selection of progeny with the best collection of desired traits. Desired traits are improved upon by constant selection, a process that involves thousands of trials done in different locations. A commercially available hybrid resulting from CB can take decades to obtain. Stamp and Visser (2012) state that the present outcome from CB is one variety resulting from 100,000 seeds. Efficiency in CB is quite low, and the resulting hybrids are too genetically diverse due to the crossing of entire genomes.[19] This is an important issue because farmers require genetic uniformity in their crops to ensure economies of scale in agriculture (Leisinger, 1999).

CB has been successful thus far in dealing with problems such as pests and diseases; however, it is limited by the genes available in the crop's genome. The modern biotechnological approach to plant breeding in the form of genetic modification has great potential to increase productivity while providing sustainability (Sharma and Ortiz, 2000; Trewavas, 2002). Recent progress in gene transfer technology has enabled scientists and plant breeders to go beyond a crop's genome to find better solutions to biotic and abiotic stressors. New breeding methods continue to accelerate the pace and precision of crop breeding so as to loosen constraints of agricultural production (Ortiz Rios, 2015). In essence, with this technology genetic resources can be exploited much more efficiently and breeding objectives can be attained faster. Qaim (2009) shows that throughout their short history GM crops have procured large aggregate welfare gains and can potentially provide environmental and health benefits. However, because these crops are often associated with market failures (environmental and health externalities) they are highly regulated. The regulatory and approval processes of GM crops have become a barrier to the dissemination of this potentially welfare enhancing technology.

[19] A genome is an organism's complete set of DNA.

2.4. Risks Assessment of Genetically Modified Crops

A clear distinction between risk analysis and risk assessment must be established in order to frame the GM crop debate appropriately.[20] Risk analysis comprises three components: risk assessment, risk management and risk communication. Whereas, risk assessment is a process of evaluation including the identification of the attendant uncertainties, of the likelihood and severity of an adverse effect(s)/event(s) occurring to man or the environment following exposure under defined conditions to a risk source(s). A risk assessment comprises hazard identification, hazard characterization, exposure assessment and risk characterization.[21] With the distinctions between risk analysis and risk assessment established the specific case of GM crops can be explored with greater accuracy.

Smyth and Phillips (2014) examine the politicization of risk around GM crops. They contend that while science based risk assessments have deemed GM foods safe for human and animal consumption, politicized risk assessments advocate that GM food is pernicious to human and animal health. Johnson et al. (2007) identify two reasons for such polarized views enveloping GM crops. The first is that there is accumulation of data that claim relevance for risk assessment but which answers few questions about risk. The second reason is the failure of risk assessments to address concerns that fall out of such assessments, for example: socio-political factors. It must be understood that scientific risk assessment is but one component of a larger evaluation of the desirability of adopting GM crops. Thus, a potential barrier to the adoption of the technology is the concession of a political hue to risk assessments. Opposing approaches to risk assessment can be observed between the US and the EU, with the latter granting a political hue to risk assessment.

2.4.1. External Influence of Agri-Biotech Policy

Both the US and EU member states are characterized by pluralist interest groups. These groups tend to shape policies by influencing political agendas and policy-makers' choices via lobbying. Bernauer and Aerni (2007) argue that these groups compete for public trust and try to manage it like a private resource. The possession of public trust provides them with legitimacy,

[20] Definitions of terms in this section are reproduced from the 'First Report on the Harmonization of Risk Assessment Procedures' (European Commission, 2000).

[21] Hazard is defined as the potential of a risk source to cause an adverse effect (s)/event(s).

which in turn translates into political power. The combination of public trust and legitimacy are important sources of discursive power. This type of power is understood by Bernauer and Aerni (2007) as the ability to influence norms, values, ideas, and political agendas. For them, it is the quest for public trust and discursive power in developed countries that has shaped agri-biotech policy in developing countries.

Many (if not all) of the controversies surrounding GM crops are based on hypothetical claims by supporters and opponents of the technology in advanced countries. With a more pragmatic approach to agricultural biotechnology, foreign influence in regulatory agendas of developing countries could become less effective. It is important to note that although most GM crops have been tailored to the needs of farmers in developed countries, higher yield and income gains are observed in developing countries from the adoption of these crops (Klümper and Qaim, 2014). The establishment of domestic regulatory frameworks and the undertaking of assessments of GM technology, would likely free developing countries from importing paradigms that adoption of technologies from developed countries entails (Weiss and Bonvillian, 2013). Another important step to reduce the uncertainty as to what would happen should these crops be commercially adopted is to undertake economic impact assessments. These last two points are the focus of the remainder of this literature review.

2.5. Salvadoran Biosafety Framework and Regulations

For to the specific case of ES and its consideration of licensing of GM IR maize. Adoption of GM maize would not require the establishment or development of new laws or regulatory bodies in the country. The 'Law of the Environment' in Article 21 lays out which activities are to present an environmental impact study (EIS). Letter 'ñ' of this article states that: "biotechnology projects or industries, or anything that implies the use of genes or production of genetically modified organisms" must present an EIS.[22] Article 68 states that the Ministry of the Environment and Natural Resources (MARN), with the aid of specialized institutions, will

[22] Original Article 21 of the Law of the Environment and letter 'ñ' in Spanish: "Toda persona natural o jurídica deberá presentar el correspondiente Estudio de Impacto Ambiental para ejecutar las siguientes actividades, obras o proyectos"; "Proyectos o industrias de biotecnología, o que impliquen el manejo genético o producción de organismos modificados genéticamente".

enforce the norms to which varieties resulting from biotechnology are to be subjected, so as to minimize the impact on native biodiversity (LMAE, 1998). [23]

El Salvador has also signed and ratified the Cartagena Protocol on Biosafety (CPB), which sets out the procedures on the safe transfer, handling and use of living modified organisms (LMOs) resulting from biotechnology. Based on these two documents a further step was taken in order to consolidate a biotechnology regulatory framework. In 2008, the ‘Special Rules for the Safe Handling of Genetically Modified Organisms’ was developed (REMSOMG, 2008). The rules and guidelines lay out the security norms to which varieties resulting from modern biotechnology are to be subjected to (these are not extended to include humans, i.e. only animals and plants). Upon the examination of the texts of the law of the environment, the ‘Special Rules for the Safe Handling of Genetically Modified Organisms’ and the CPB text, little room is left to hermeneutics. For ES, a next step in its licensing consideration process of GM IR maize would be the undertaking of an economic impact assessment of the technology.

2.6. Approaches to the Assessment of Genetically Modified Crops

There are many suitable approaches for the *ex-ante* economic evaluation of GM crop technology. Two approaches are explored in depth in the following sections. Either, real option value models or the economic surplus approach would be appropriate to evaluate GM IR maize adoption in El Salvador. However, the latter was chosen due to practicality, familiarity and the availability of data.

2.6.1. Real Option Value Models Approach

Investment is defined as the act of incurring an immediate cost in the expectation of a future reward or rewards. Dixit and Pindyck (1994) identify three important characteristics that most investment decisions share: (1) the investment is partially or completely *irreversible*; (2) there is *uncertainty* over the future rewards from the investment; and (3) there exists some leeway about the *timing* of the investment. The last characteristic means that while complete information or certainty is unattainable, a decision can be delayed in the hope of obtaining more

[23] Original Article 68 of the Law of the Environment in Spanish: “El Ministerio, con el apoyo de instituciones especializadas, aplicará las normas de seguridad a las que habrá de sujetarse las variedades resultantes de la acción humana mediante la biotecnología, supervisando su empleo a fin de minimizar el impacto adverso sobre la diversidad biológica nativa”.

information. The interaction of these three characteristics served as the base for the development of their theory of irreversible investment under uncertainty. The theory demonstrates that optimal investment rules can be obtained from methods developed for pricing options in financial markets.

Furtan et al. (2003) employed real option value models to determine the optimal time to license GM wheat in Canada.[24] They substantiate that the policy decision to license GM wheat needs to account for the uncertainty, irreversibility and potential externalities of the technology. To this effect, they identified two potential externalities that could result from the decision to license GM wheat. First, there was a potential for introgression of GM wheat into non-GM crop fields thereby imposing greater herbicide costs on non-adopters.[25] Second a potential loss in aggregate producer surplus because of consumer rejection of GM wheat. Due to GM wheat not being licensed anywhere (at that moment), the real options framework was considered appropriate for that case because of its flexibility in the timing of the optimal licensing decision. However, employing this methodology to economically assess the potential impacts of GM crops requires advanced knowledge of statistics, finance and economics, which does not make it the most practical (or familiar) methodology available to assess the impact of GM crops. This methodological complexity makes it difficult for policy makers in developing countries to fully understand the impacts of GM technology.

2.7. Economic Surplus Approach

A more common approach for analyzing the welfare and distribution effects from the adoption of technology in a partial-equilibrium framework is the measurement of economic surplus. Griliches (1958) was among the first to use this concept when he evaluated the impact the introduction of hybrid maize had in the US. More recently, Alston, Norton, and Pardey (1995) describe the economic surplus model as consisting of a set of supply and demand equations that model the market as a system. Mathematic manipulations of these equations permit the estimation of total surplus and its disaggregation into consumer, producer, and innovator surplus. In applied analysis, the economic surplus model is incorporated by making

[24] At the time their analysis took place, the Canadian Wheat Board still existed. The Canadian Wheat Board was a single desk seller that marketed producers' wheat and barley in Western Canada.

[25] Introgression is the movement of a gene (gene flow) from one species into the gene pool of another.

assumptions on certain parameters, such as: the size and openness of the economy; demand and supply elasticities; magnitude and nature of the shift in supply; and the adoption rate and path of the technology (Falck-Zepeda et al., 2000; Napasintuwong and Traxler, 2009; Qaim and von Braun, 1998).

The results from applying such a method are sensitive to the assumptions made. Hence, sensitivity analysis is conducted to assess the robustness of the results obtained. Falck-Zepeda et al. (2000; 2013) draw on the work of Davis and Espinoza (1998) to extend the economic surplus model by incorporating stochastic elements so as to provide a more rigorous sensitivity analysis of model parameters. This methodology requires a variety of estimates to be available (or drawn from literature) for the different parameters for the elaboration of subjective probability distributions (Zhao et al., 2000). Regardless of the variation of economic surplus method used, underlying this approach is a large body of theory (Just et al., 1982), and the underlying assumptions of the approach are not always explicitly stated. Harberger (1971, p. 785) set forth three postulates that he considers provide a conventional framework for applied welfare economics. Those postulates are:

1) The competitive demand price for a given unit measures the value of that unit to the demander;

2) The competitive supply price for a given unit measures the value of that unit to the supplier; and

3) When evaluating the net benefits or costs of a given action (project, program, or policy), the costs and benefits accruing to each member of the relevant group (e.g. a nation) should normally be added without regard to the individuals (s) to whom they accrue.

With these assumptions, consumer benefits from consumption can be measured by computing the area beneath a Marshallian demand curve. The area beneath the supply curve is a measure of total costs, thus, changes in producer welfare can be computed by using producer surplus.

Despite the large body of literature and many applied studies using the partial-equilibrium economic surplus model, the approach is not without criticisms. Mainly those are: measurement errors, ignoring externalities, transaction costs, and effects in other markets (general equilibrium effects). However, its use is still justified when appropriate assumptions about the impacts of technology are made. A concise explanation of the methodology used to measure economic surplus due to GM IR maize adoption in El Salvador is presented in the next chapter.

2.8. Summary

Innovation is imperative to not only the survival of firms but to the economic development of entire countries as well. Although it is understood that knowledge underlies innovation, what is just recently coming into focus is that 'people' are the best channel for knowledge transmission. Canada's critical assessment of its own scientific research undertaking and its subsequent translation into practical solutions to societal problems has shed more light on this fact. Endogenous growth theory examined from two different perspectives summarizes this fact. In essence the theory holds that economic growth can be greatly contributed to by investing in human capital and knowledge. Lucas' argument in particular that knowledge is universal, but what is different is the knowledge possessed by different groups of people, is relevant in the modern biotechnological industry. Scientists have greatly shaped this industry and the constant progress has led to more sophisticated innovations.

Genetic modification is one such innovation of modern biotechnology. The knowledge of scientists (acquired at universities) trained in molecular biology gave way to novel innovations that have loosened constraints imposed on agriculture. These innovations were not controversial until they were oriented towards aiding farmers and the food resulting from this aid made it to market. Thus, regulatory bodies were enacted to monitor the safety of the technology. Currently however, risk assessment in certain parts of the world has taken on a political hue. This paradigm can potentially over emphasize risks associated with these innovations and overlook benefits.

In a more pragmatic approach to modern biotechnology, El Salvador has elaborated and established its own modern biotechnology regulatory framework. This approach to modern biotechnology led the country to the signing and ratifying of the CPB. Because field trials have been undertaken in ES, data to project the economic impacts a GM IR maize hybrid could have in the country is now available. Chapter 3 presents the methodology employed to measure economic surplus resulting from GM IR maize adoption in El Salvador.

Chapter 3. Methodology

3. Introduction

The economic impact of adopting a transgenic hybrid can be assessed before or after its licensing. *Ex-ante* methodologies are used to assess GM crops not yet commercially available and *ex-post* methods are used to assess the impact of the technology after its commercial adoption. It can be argued that *ex-ante* methodologies are done too early i.e. when nothing is observable. However, a drawback of evaluating technology only after its commercial adoption is that results cannot serve as guidelines for the optimization of the technology's socioeconomic effects. The purpose of this chapter is to explain the methodology used in this thesis and justify the values assigned to the parameters employed in the model. Two trade agreements are identified and explored in depth because one would have direct implications should GM maize adoption occur, and the other would be indirectly impacted by this decision.

3.1. Conceptual Framework

Assessment of potential costs and benefits of GM crop technology serves to bridge the gap between the generation of this technology in the laboratory and its commercial adoption (Babu and Rhoe, 2003; Vanclay et al., 2013). There are many *ex-ante* methods of economic assessment, each with advantages and limitations depending on the availability of data, the distinct GM crop and its corresponding externalities (Table 3.1). An economic projection was the most appropriate method to assess GM maize adoption in El Salvador because field trials evaluating these crops have been undertaken.

Field trials provide information on critical variables such as the increase in yield and reduction in pesticide use the technology offers. Based on this information and Salvadoran maize market data, aggregate economic surplus from GM IR maize adoption was projected over ten years.[26] Aggregate surplus was disaggregated into consumer surplus (CS), producer surplus (PS), and gross technology revenue (π) accruing to the biotechnology firm in the GM maize seed input

[26] This time period seems appropriate because after ten years the degree of pest abatement these hybrids procure might change (decline). Though evidence of this has not been observed for GM IR maize hybrids as of yet (Riesgo et al., 2012).

market. Calculations are carried out for all the years of the consideration period (ten years) in which supply curve shifts are expected to be caused by GM IR maize adoption.

Table 3.1. *Ex-Ante* Methods of Economic Assessment and Respective Example

Method	Examples
Partial Budget Approach	Alston, Hyde, Marra, and Mitchell, (2002)
Cost-Benefit Analysis	Flannery, Thorne, Kelly, and Mullins (2004)
Economic Projection	Falck-Zepeda, et al., (2012) Qaim (2003)
Stochastic Economic Surplus	Falck-Zepeda, Traxler, and Nelson (2000) Hareau, Mills, and Norton (2006) Falck-Zepeda, Horna, and Kyotalimye (2013) Naseem and Singla (2013)
Dynamic Research Evaluation and Management Model	Napasintuwong and Traxler (2009)
Computer General Equilibrium	Moschini, Lapan, and Sobolevsky (2000)
Multi-Market Model	Moschini, Bulut, and Cembalo (2005)

Source: Author.

As discussed in Chapter 2, Alston, Norton, and Pardey (1995) developed several approaches for the economic evaluation of agricultural technology resulting from R&D. For each approach they weighed the pros and cons concluding that the use of commodity-market-oriented economic surplus models are the most practical approach for technology assessment. Their methodology to the economic surplus approach was adapted in this study to evaluate the potential impacts GM IR maize adoption could have in El Salvador. However, modern agricultural biotechnology innovations are mostly generated by private firms and they are typically protected with intellectual property rights (IPRs) (Rausser et al., 1999). Thus, to account for the gross technology revenue to the innovating firm an approach similar to the one proposed by Moschini et al. (2000) and employed by Falck-Zepeda et al. (2000), Krishna and Qaim (2008) and Qaim (2003) was used.

3.2. Methodology

Beginning at an initial price and quantity equilibrium in the Salvadoran maize market, the new GM IR maize variety is expected to increase the productivity of maize production and therefore cause the maize supply curve to shift downwards. Conceptually, this can be seen in

Figure 3. The adoption of GM maize would likely shift the supply curve downward from S_0 to S_1; whereas, demand was assumed to remain unchanged. Linear curves and a parallel shift in supply were assumed in order to model the impact of GM maize adoption in El Salvador (Rose, 1980). S_0 and S_1 are the annual domestic maize supply curves without and with the introduction of GM IR maize, respectively. The price of GM maize will decrease from P_0 to P_1 because of the expected decrease in costs and increase in maize produced. As a result, consumer surplus increases equal to P_0abP_1, the change in producer surplus is equal to the area $P_1bI_1 - P_0aI_0$, and total surplus increases equal to the area I_0abI_1. K is the parallel shift in the supply curve stemming from the introduction of the of GM IR maize.[27]

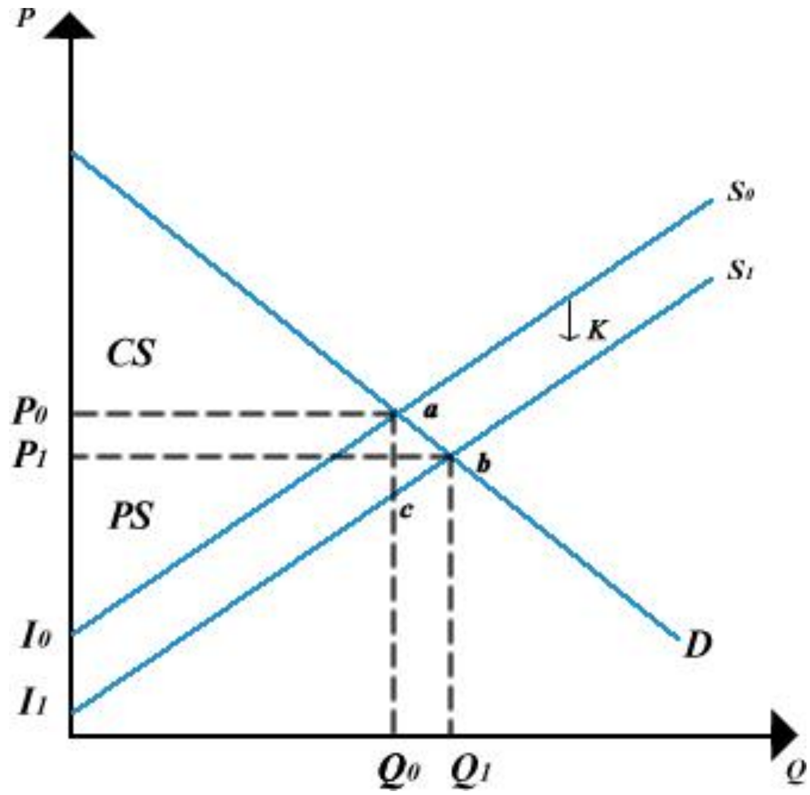

Figure 3.1.Change in Economic Surplus from GM Maize Adoption in El Salvador

Source: Adapted from Alston et al. (1995) p. 209 and Falck-Zepeda et al. (2013) p 101.

[27] Whether K is pivotal or parallel along the along the supply curve has been widely discussed in the literature without a definitive answer available for either choice (Norton and Davis, 1981).

Since Salvadoran maize imports and exports are minimal, closed economy scenarios were assumed. That is, equilibrium price was assumed to be entirely determined by domestic supply and demand. The reasoning behind this assumption is addressed in section 3.6.1.

3.2.1. The Model

Following Alston et al. (1995), the annual change in producer surplus (ΔPS_t) and consumer surplus (ΔCS_t) from the adoption of GM IR maize can be calculated as:

$$\Delta PS_t = P_t Q_t (K_t - Z_t) (1 + 0.5 Z_t \eta) \quad (3.1)$$

$$\Delta CS_t = P_t Q_t Z_t (1 + 0.5 Z_t \eta) \quad (3.2)$$

P_t and Q_t are the initial equilibrium price and quantity. K_t is the parallel shift in the supply curve in year t due to GM IR maize adoption and is estimated as:

$$K_t = \{[E(Y)] / \varepsilon - [E(C)] / [1 + E(Y)]\} \, p \, A_t (1 - \delta_t) \quad (3.3)$$

Where $E(Y)$ is the expected proportionate yield change per hectare, ε is the price elasticity of supply, $E(C)$ is the proportionate change in variable input costs per hectare to achieve the expected yield change, p is the success rate or the probability that GM maize will achieve the expected yield, At is the adoption rate (proportional area of GM maize to total maize production area in year t),[28] and δ_t is the rate of annual depreciation of GM maize (reduction of expected yield) in year t. p is given a value of 1 because field trials have been done confirming that the an 18% yield increase is achievable. δ is assigned a value of 0 because no decrease in yield is anticipated during the consideration period (ten years).[29]

Z_t is the absolute value of the reduction in price as a result of the supply shift and can be calculated as:

$$Z_t = K\varepsilon / (\varepsilon + \eta) \quad (3.4)$$

Where η is the absolute value of the price elasticity of demand.

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[28] This parameter is explained in greater detail in section 3.4.5.

[29] This parameter means that GM IR maize would not provide the same degree of pest abatement at some point, thus decreasing the yield the hybrid provides. However, in neighboring Honduras where GM IR maize has been commercially available for more than a decade, as of yet, there is no report of pest abatement decline (Falck-Zepeda et al., 2012). Which is why for the projection in this study that only contemplates ten years, no decline in yield was anticipated.

Following Moschini et al. (2000) innovator surplus is computed as:

$$\pi_t = Q_{GM\,IR}\,(P_{GM\,IR} - P_c) \tag{3.5}$$

Where π_t is the surplus accruing to the innovating firm providing GM IR maize seed in year t. $Q_{GM\,IR}$ is the potential coverage of GM IR maize in hectares, $P_{GM\,IR}$ is the price charged for GM IR hybrid seed per hectare, and P_c is the price of conventional hybrid seed. Once a commercial GM crop has been developed, the seed reproduction process is identical for GM and non-GM crops. It is assumed that the conventional hybrid seed market is competitive, P_c represents the marginal cost of seed production, which is the same for conventional and GM IR maize hybrids. Hence, $P_{GM\,IR}$ - P_c is the gross GM IR maize seed revenue from which no administrative, marketing, or IPRs enforcement costs are deducted. GM IR maize seed development costs are assumed to be sunk and are not contemplated in the observed pricing decision.
Change in total surplus (ΔTS) then can be computed as follows:

$$\Delta TS = \Delta PS + \Delta CS + \pi \tag{3.6}$$

In the model, impacts are assumed to accrue for the entirety of the consideration period (ten years) after initial adoption, which was assumed to be in 2016. Thus, the net present value (NPV) is calculated from annual surpluses as follows:

$$\text{NPV} = \sum_{t=0}^{10} \frac{\Delta TS}{(1+r)^r} \tag{3.7}$$

$$\text{NPV} = \sum_{t=0}^{10} \frac{\Delta CS}{(1+r)^r} \tag{3.8}$$

$$\text{NPV} = \sum_{t=0}^{10} \frac{\Delta PS}{(1+r)^r} \tag{3.9}$$

$$\text{NPV} = \sum_{t=0}^{10} \frac{\pi}{(1+r)^r} \tag{3.10}$$

r is the discount rate. Following Napasintuwong and Traxler (2009) and Hareau et al. (2006) a discount rate of 5% was used. The following sections describe the maize sector of El Salvador and justify values assigned to the model's parameters.

3.3. Maize Production, Area and Average Yield

By 2009, 91% of maize seed sown in El Salvador was certified hybrid seed, the remaining 9% of was criollo or local seed (Olson et al., 2012).[30] It was thus assumed that 90% of area is sown with hybrid maize seed. Table 3.2 shows that area sown with white maize has tended to fluctuate over the past 19 years. The average of 266,822 hectares was used as the base area i.e. maximum possible area sown with maize. Total production (measured in MT) has also fluctuated between a minimum of 501,630 MT and a maximum of 925,839 MT. To reconcile this difference, the average was taken to project the potential impacts of GM IR maize adoption, that is, 700,896 MT.[31] From 2004 to 2013, with the exception of 2006 and 2014 due to drought, yield per hectare has been at least 2 MT. To reduce variability, the average between 1996 and 2014 was used, that is, 2 MT. All three averages (total area, total production and yield per hectare) were incorporated into the equations of the model.

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[30] Certified hybrid seed has been submitted to a production process that has been supervised and officially certified by a seed certification organism and it gathers the minimum requirements of genetic purity, quality and identity (Ferrufino, 2009 p. 4). In contrast, criollo is a seed landrace autochthonous to ES.

[31] This data comes from reports MAG publishes on a yearly basis. However, recent reports do not go as far back as 1996, thus, older reports were consulted to obtain absent data. An anomaly arose when scrutinizing the data. In the 2012 report, total production reported for 2004 through 2006 is not the same as the total production reported in the 2007 report for those same years. This study used the values the 2007 report specifies from 1996 until 2003. The values from 2004 through 2011 are taken from the 2012 report.

Table 3.2. El Salvador: total maize area, production and average yield per hectare			
Agricultural Cycle	**Area (ha)***	**Production (MT)****	**Average Yield (MT/ha)**
1996	279,090	622,491	1.6
1997	306,145	501,630	1.1
1998	295,400	556,418	1.3
1999	263,410	651,936	1.7
2000	259,259	576,055	1.6
2001	294,105	564,977	1.3
2002	247,441	637,040	1.8
2003	228,962	627,980	1.9
2004	220,424	662,277	2.1
2005	257,057	820,949	2.2
2006	244,108	615,023	1.8
2007	240,530	699,416	2.0
2008	256,420	868,259	2.4
2009	261,890	785,965	2.1
2010	253,894	768,113	2.1
2011	268,392	756,352	2.0
2012	284,262	925,839	2.3
2013	294,483	866,701	2.1
2014	314,343	807,900	1.8
Average	**266,822**	**700,896**	**2.0**

Source: MAG (2015)
***** Hectare.
**Metric Ton

3.3.1. Average Per-Hectare Maize Cost Structure

In order to better portray the potential impact of GM IR maize adoption, the cost structure of the most employed conventional maize hybrid (H-59) among Salvadoran farmers is portrayed in Table 3.3. It was adapted from the cost structure developed by the Ministry of Agriculture and Animal Husbandry (MAG) and is assumed to be sufficiently representative of production costs of all of El Salvador. MAG developed the cost structure on the assumption that 2.3 MT of maize would be produced per hectare. A yield that is in contrast with the recorded average yield per hectare during the last 19 years (Table 3.2.). According to the cost structure, pesticide and the labor required to apply it represent 9% of total cost in conventional maize production. It was assumed that during the consideration period (ten years), except for what GM IR maize alters, all other cost components remain unchanged even with gradual adoption.

Table 3.3. Maize Production Per Hectare Cost Structure For El Salvador

Cost Component	Labor Days	Unit Cost USD	Partial cost		Total Cost USD
Land Preparation					**244.04 (23.29%)**
Manual Weed Control	6	5.23	31.38		
Seeding					
Seeding	6	5.25	31.5		
Crop Work					
First Fertilization	3	5.30	15.9		
Second Fertilization	3	5.28	15.84		
Third Fertilization	1	5.25	5.25		
First Weed Control[1]	3	5.20	15.6		
Hilling-Up	9	5.23	47.07		
Lifting of Plants	1	5.10	5.10		
Application of Pesticides and Foliar Fertilizer	10	5.46	54.6		
Crop Manager	3	5.45	21.8		
Inputs*	**Unit**	**Quantity**	**Unit Cost USD**	**Partial Cost USD**	**Total Cost USD**
Certified Seed	100 lbs.	36.00	2.06	74.16	**533.15 (50.89%)**
Formulated Fertilizer	100 lbs.	9	30.51	274.59	
Ammonium Sulfate	100 lbs.	6.3	18.95	119.4	
Pesticides and Foliar Fertilizer				65.00	
Cost of Vegetative Development of the Crop					**777.19**
Harvest	**Labor Days**	**Unit Cost USD**	**Partial cost**		**Total Cost USD**
Folding of Stalk	7	5.19	36.33		**99.48 (9.49%)**
Maize Gathering	9	5.29	47.61		
Crop Manager	3	5.18	15.54		
Machinery Used in Harvest		Machinery			**85.65 8.17%**
	Quantity MT	**Unit Cost USD**	**Partial Cost USD**		
Grain Separation (100lbs.)	2.8	0.92	57.50		
Internal Transport (100 lbs.)	2.8	0.45	28.15		
Direct Costs					**962.32**
Management					**8.40**
Incidentals					**14.00**
Indirect Costs					**22.4 (2.13%)**
Land Rental**	**Unit**	**Quantity**	**Unitary Cost**	**Partial Cost**	**Total Cost USD**
Land Rental	Hectare	1.00	63	63	**63 (6.01%)**
Total Cost					**1047.72 (100%)**
Cost Per Unit	Metric Ton				**374.18**

Source: Adapted from Ochoa et al., 2013 p. 5

Notes: The cost structure is estimated based on an expected yield of 2.3 MT/ ha.

[1] Low cost of first manual weed control is due to the use of herbicides i.e. a chemical control of weeds is done.

* Inputs were rounded to the nearest whole unit when projected for hectares.

**Also considered the opportunity cost of the hectare of land.

3.4 Genetically Modified Maize Field Trials

Maize production and maize productivity enhancement is a priority of Salvadoran agricultural authorities. With this as a primary objective, at the end of 2008 and beginning of 2009 through CENTA, field trials evaluating GM maize were undertaken in El Salvador. Two different gene developers provided four different GM maize hybrids for field evaluation. Two hybrids, one with herbicide tolerance (HT) and the other with insect resistance (IR) and herbicide tolerance were provided by Monsanto (gene developer 1).[32] Two *Bacillus thuringiensis* (*Bt*) maize hybrids resistant to certain insects were provided by DUWEST Pioneer (gene developer 2). Combined, the agribusiness firms that supplied the transgenic hybrids control 78% of the Salvadoran conventional maize seed market. Both firms have a stronghold in the Salvadoran maize seed market and are widely known throughout the country's farmers.

Figure 3.2.Map of Maize Cultivation within El Salvador and Location of GM Maize Field Trials

Source: Adapted from Ortez Andrade et al. (2015).

Field trials were conducted at three experimental stations (depicted with red stars) in different parts of the country (Figure 3.2). The primary focus of the field trials was to evaluate the degree of pest abatement against the three most damaging pests to maize production (fall armyworm, maize stalk borer, and maize earworm). Pest abatement of GM maize hybrids was

[32] This study is only concerned with the welfare and distribution effects due to the adoption of GM IR maize. HT maize adoption is not contemplated in this study. In fact, Trigo (2011) found that HT maize was of little interest to maize producers in Argentina because they preferred a hybrid with 'stacked' traits.

evaluated under three different crop management programs: (1) 'Recommended', which is the crop management program farmers should use when cultivating a GM maize hybrid; (2) 'Traditional', which is the crop management program a farmer typically employs when cultivating conventional maize in El Salvador; (3) and 'Witness' which is the crop management program in which no pest control was done. For every GM maize hybrid evaluated under the witness crop management program, only manual weed control was done.

Land preparation for all field trials consisted in the three time plowing of the plot of land. Sowing was done manually at a distance of 0.2 m between plants and 0.8 m between rows for a plot of 24 m^2 for the hybrids Pioneer provided and 32 m^2 for the hybrid Monsanto provided.[33] Per biosafety suggestions of the 'Ministry of the Environment and Natural Resources' (MARN), a barrier of four rows of conventional maize was sown around the experimental plots. Field trials were conducted during the dry season (November through May), therefore all maize evaluated was under irrigation. All hybrids followed the same fertilization plan, which consisted of 220 kg of nitrogen, 120 kg of phosphorus and 60 kg of potassium administered in three applications.

3.4.1. Results from Hybrids provided by Gene Developer 1

Management of the hybrid DK234YGRR was much different from conventional management.[34] Roundup® was sprayed directly onto DK234YGRR to control weeds (1.5 to 3.5 kg/ha depending on the type of weed). Pest control was done according to YieldGard® + Roundup Ready Maíz2® technology. Fall armyworm damage was always below the economic threshold, thus, not high enough to justify a pesticide application.[35] Maize earworm damage was the least in DK234YGRR when compared to any of the other GM IR maize hybrids evaluated. The stem of the plant was well protected against the actions of maize stalk borer as well.

[33] This is equivalent to a plant density of 62,500 plants per hectare.

[34] A learning curve might have to be accounted for should licensing of this hybrid occur.

[35] A threshold of 20% damage was established to be the least amount of damage that economically justifies an application of pesticide.

Table 3.4 GM IR Hybrid provided by Gene Developer 1 compared to H-59 Hybrid.				
Experimental Station	**Recommended[1] Yield Increase (%)**	**Traditional[2] Yield Increase (%)**	**Witness[3] Yield Increase (%)**	**Average Yield Increase (%)**
Izalco	18	14	25	19
San Andres	19	12	13	15
San Vicente	18	31	25	25
Country Average				20

1- It is the crop management plan recommended when cultivating this hybrid.

2- Is the crop management plan farmers typically use when cultivating hybrid H-59.

3- No application of pesticides was made. Manual control of weeds was the only agronomic job done.

At the San Vicente experimental station, the Traditional crop management program registered the highest increase in yield, 31% above H-59 (Table 3.4). However, the witness crop management yield increase of 25% above H-59 at Izalco and San Vicente is the most informative. These results imply that should subsistence farmers adopt this hybrid and only administer fertilizer, they are securing at least 25% more maize for themselves. Country wide, this hybrid registered a minimum increase in yield of 13% and a maximum of 31% above the conventional hybrid H-59.

3.4.2. Results from Hybrids provided by Gene Developer 2

For the purposes of field evaluation, the hybrids 30F32HW and 30F83HW were grouped under GM maize i.e. no distinction was made between these two hybrids. Field evaluation determined that the use of either of these hybrids does not require the spraying of pesticides. Both fall armyworm and maize stalk borer damage was well below the economic threshold established. Though damage caused by maize earworm was below the economic threshold, it still proved to be esthetically unpleasing. An oddity arose when undertaking these field trials. Extreme weather conditions destroyed the field trial plot in Izalco leaving only the other two stations with data to report.

Table 3.5.GM IR Hybrids provided by Gene Developer 2 compared to H-59 Hybrid				
Experimental Station	**Recommended[1] Yield Increase (%)**	**Traditional[2] Yield Increase (%)**	**Witness[3] Yield Increase (%)**	**Average Yield Increase (%)**
Izalco*	-	-	-	-
San Andres	23	21	4	16
San Vicente	22	10	7	13
Country Average				15

1- It is the crop management plan recommended when cultivating this hybrid.

2- Is the crop management plan farmers typically use when cultivating hybrid H-59.

3- No application of pesticides was made. Manual control of weeds was the only agronomic job done.

*Adverse weather conditions destroyed the GM maize field trial, thus so no measurements were able to be taken.

The highest yield increases were registered under the 'recommended' crop management regime at San Andres and San Vicente (Table 3.5). It seems that farmers benefit the most when adhering to technology recommendations when cultivating these hybrids. Country wide, this hybrid registered a minimum increase in yield of 4% and a maximum of 23% above the conventional hybrid H-59. For the economic projection of welfare and distribution effects from GM IR maize adoption, a global average was taken. That is, the average yield increase from both gene developers was taken (18% yield increase).[36] In neighboring Honduras an increase of between 17% and 36% in yield from GM IR maize adoption was reported (Falck-Zepeda et al., 2012). The yield increase assumption is comparable to what is observed in other countries.

3.4.3. Field Trial Conclusions

Consistently, GM IR maize outperformed the conventional hybrid H-59. These results could be easily criticized because average farmers will not easily replicate field trial conditions. This may have overrated productivity effects and may have led to the so called 'yield-gap' phenomenon (Davidson et al., 1967). Field trials were conducted on small plots with 0% gradient under the strict management of CENTA agronomists. Adequate amounts of fertilizer and pesticides were administered, opposed to the modest amounts average farmers use because the

[36] This is because it is not known how much GM maize seed each gene developer will provide.

use of such inputs is not always an economical option. GM IR maize evaluation took place during the dry season, which means all hybrids were under irrigation (adequate amounts of water were supplied) and pest pressure was different when compared to the rainy season, which is when most maize production takes place. However, this is the methodology chosen to conduct field trials by Salvadoran authorities. And it is the data provided by these field trials that was incorporated into the economic projection of GM IR maize adoption.

3.5. Remaining Model Parameters Values

3.5.1. Equilibrium Price (P_t)

Salvadoran records on the price of maize were missing data for seven years.[37] Domestic price per MT of maize was searched for in other locations such as the MINEC and the Central Bank of El Salvador (BCR) without success. In the absence of the price for these years and so as to not overstate the price per MT of maize, interpolation was done.[38] Over the period 1996-2014, a price of $255 per MT of maize was derived. This price was assumed to be the equilibrium price for maize.

3.5.2. Genetically Modified Insect Resistant Maize Seed Price ($P_{GM\ IR}$)

The price of $130 per bag of 60,000 GM IR maize seeds in Honduras was used as a proxy because no price or estimate of a price for a GM IR maize variety exists in El Salvador.[39] According to field trial data, 62,500 maize plants per hectare is the ideal plant density. A bag of 60,000 seeds was assumed to be sufficient for the sowing of one hectare of land. Thus, $130 for the price of seed per ha was assumed. However, an important issue came into focus. Currently, the total cost of seed per ha is $74.16 (Table 3.3). If the price of GM IR maize seed is too high, will the government continue the subsidy to maize farmers? It is important to note that farmers not only receive seed, but 100 lbs. of ammonium sulfate as well. To a financially constrained country with many social problems as El Salvador is, an increase in the cost of the subsidy program may become too much. As such, a scenario in which the government discontinues the subsidy was also simulated.

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[37] The years missing are: 1997 through 2000 (four years), 2007, 2008 and 2011.

[38] Interpolation is a method of constructing new data points within a range of known data points. This was done using the '*Linear Forecast*' function in *Excel*, using the known prices per MT of maize.

[39] Personal contact was established with a seed provider in Honduras in order to obtain this price.

3.5.3. Expected Increase in Yield (*E(Y)*) and Change in Variable Input Costs (*E(C)*) per Hectare

Although El Salvador is located in the tropics where pest pressure is severe (Oerke et al., 1994), GM IR maize provides an 18% increase in yield. Furthermore, agronomic evaluation concluded that the economic threshold necessary to justify an application of pesticide was not reached in any trial. This means that the cost of pesticide and the labor necessary to apply it are eliminated from the maize production cost structure. This translates into an overall 9% decrease in total production costs. That is, once seed price is adjusted (increased from $74.16 to $130) and the pesticide component (and the labor that entails) is removed from the cost structure, 9% is the reduction in costs per hectare.

3.5.4. Price Elasticity of Supply (ε) and Demand (η)

Own-price elasticity of supply (ε) for maize in El Salvador was not available. In its absence, the value Iowa State University's Food and Agricultural Policy Research Institute (FAPRI) suggests for Mexico of 0.22 was used. Own-price elasticity of demand *(η)* was also not available for El Salvador, in its absence the elasticity of demand for maize of Mexico, which is -0.12, was used. Mexico was chosen because of geographical proximity and cultural similarity to El Salvador.

3.5.5. Adoption rate (A_t)

Adoption rates are very difficult to derive and highly uncertain in *ex-ante* analyses. They have a large effect on the magnitude of total Marshallian surplus change. In El Salvador, 91% of maize area is sown with certified hybrid seed, which means that each year this seed must be obtained from a seed supplier (Ferrufino, 2009). Due to the fact that GM maize varieties have been available for more than a decade in neighboring Honduras, its adoption rate was considered to serve as a proxy. However, Falck-Zepeda et al. (2012) citing another study determined that after many years of private and public efforts to promote improved maize varieties, adoption was still less than 20%. It was unreasonable to use this figure because 91% of maize seed planted in El Salvador is certified. Moreover, when eliciting an adoption rate, the porousness of the border between El Salvador and Honduras is also a factor that must be taken into account. Illegal trafficking of merchandise between both countries has long been acknowledged (El Herlado;

Fusades, 2014). It is also suspected that because of this, GM IR maize seed may already be cultivated within the geographical border of El Salvador, albeit in a small scale.

Thus, the initial adoption rate for the scenario in which farmers must acquire transgenic seed was assumed to be 30%. For the scenario in which the transgenic seed is provided by the government through its subsidy program, the initial adoption rate was assumed to be 52%.[40] Due to 91% of maize seed sown in the country being hybrid, a maximum adoption ceiling of 90% GM IR maize adoption was assumed to be reached within ten years. Theoretically dis-adoption of GM hybrids is expected to occur at some point, although no report was found of such a practice for a GM crop thus far (Riesgo et al., 2012). The logistic adoption curve was elicited using the formula employed by Griliches (1957) and that Alston et al. (1995) suggest:

$$A_t = A^{MAX} / 1 + e^{-(-\alpha + \beta_t)} \quad (3.11)$$

Where A^{MAX} is the maximum adoption rate. A_t is the adoption rate $_t$ years after the licensing of GM maize. α and β are parameters that define the path of the adoption rate that asymptotically approaches the maximum. The entire curve was generated by defining three points. Namely, A^{MAX} which was determined to be 90% because that is the ceiling of adoption and the initial adoption of 30% in one scenario and 52% in the other.

With that information β can be expressed as a function of α, A^{MAX}, A_t and t.

$$\beta = [\ln (A_t / A^{MAX} - A_t) - \alpha]\ 1 / t \quad (3.12)$$

3.6. Trade Considerations

The objective of this section is to explain the potential impacts of GM IR maize adoption on trade agreements El Salvador is currently engaged in. Information of GM crop adoption in other countries was considered so as to reduce uncertainty regarding the implications of the technology. The licensing of GM IR maize is an example of an irreversible decision that will likely cause environmental, market and trade externalities. That is, once a GM IR maize hybrid is grown by farmers it would be almost impossible to reclaim GM genes from the environment.

[40] As was established in Chapter 1.

With this concept clarified, trade came into focus because GM crops have caused trade challenges between countries (Isaac et al., 2004).

El Salvador has a small open economy. Currently there are nine active free trade agreements (FTAs) with different regions or countries with which the country trades (MINEC, 2016). In the event of GM IR maize licensing, two of the nine FTAs could be impacted by the adoption of this technology. The first, is the Dominican Republic-Central American Free Trade Agreement (CAFTA-DR) with the US. Under this agreement El Salvador has agreed to gradually open its maize market to the US by establishing a tariff rate quota (TRQ) for white maize. The second, the EU-Central America association agreement (EU-CA) could also be impacted because of the current European stance on agricultural biotechnology.

3.6.1. Central American Free Trade Agreement

In 2004, CAFTA-DR was signed by the U.S. and five other Central American countries (the Dominican Republic became involved later). No products were excluded from the agreement and trade liberalization occurred primarily through tariff reductions and the expansion of TRQs. The US provided the same tariff treatment to each of the six countries involved, but made country-specific commitments on TRQs. The Agreement entered first into force with El Salvador on March 1, 2006.

Salvadoran exports of maize are minimal enough to consider the country a small closed economy. Within CAFTA-DR however, El Salvador granted an initial TRQ of 35,700 MT for white maize, which will expand 2% annually until year 15 of the agreement (Table 3.6). From that point onwards the TRQ will expand 700 MT annually into perpetuity. With a likely increase in production due to GM IR maize adoption and gradually increasing imports within CAFTA-DR, the effects of this agreement were comprehensively assessed and results are presented in the following chapter.

Table 3.6. Development of Salvadoran Import TRQ for White Maize Within the CAFTA-DR		
Year	**Calendar Year**	**Quota Volume (MT)**
1	2007	35,700
2	2008	36,400
3	2009	37,100
4	2010	37,800
5	2011	38,500
6	2012	39,200
7	2013	39,900
8	2014	40,600
9	2015	41,300
10	**2016**	**42,000**
11	2017	42,700
12	2018	43,400
13	2019	44,100
14	2020	44,800
15	2021	45,500

Source: Office of the United States Trade Representative

Notes: In red is the starting year of GM IR maize adoption.

3.6.2. European Union-Central American Association Agreement

Member States of the EU and Central American countries signed an agreement that established an association between both regions that relies on three pillars, namely political dialogue, cooperation, and trade (European Commission, 2016).[41] With El Salvador, the trade pillar of the Association Agreement has been provisionally applied since October 1st 2013. So as to ascertain the full ramifications the adoption of a transgenic maize variety entails the trade aspect of this agreement was explored in depth. It is likely that GM IR maize cultivation could impose externality costs on an unrelated industry, namely, the honey industry. This is because of the EU stance (and policies) on GM crops and foodstuffs derived from them. Why the licensing of GM maize could potentially impact the honey industry is explained in the following section.

[41] The Central American countries are: Costs Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama.

3.6.3. Genetically Modified Maize Adoption and its Impact on the Honey Industry

Maize is mainly wind pollinated but studies have shown that bees and other insects collect maize pollen (Bateman, 1947). For honey bees, pollen (from any flower) is the sole source of protein (Dreller and Tarpy, 2000). Danner et al. (2014) determined that for the honey bee (*Apis mellifera L.*), maize represents 'a highly relevant pollen source'. If GM maize is commercially grown in open fields in El Salvador, the impediment of GM gene transfer into the surrounding environment would be nearly impossible. Thus, it was assumed that GM maize pollen would find its way into honey produced in the country and subsequently into honey exports. As it is not known how losers and gainers from the adoption of GM IR maize adoption will be weighted, this economic analysis is limited to exploring the implications of adopting a transgenic hybrid in El Salvador. That is, a scenario in which Salvadoran honey exporters maintain their exports to the EU (following the guidelines that entails) and another in which they must turn to other trade agreements are detailed.

In 2005, a German beekeeper sued the state of Bavaria, which owned several plots of land where genetically modified MON 810 maize was cultivated for research purposes. The beekeeper claimed his honey had become contaminated with GM maize pollen. Indeed, laboratory analysis of his honey demonstrated that pollen from the maize hybrid MON 810 was present. The German beekeeper alleged that due to the mere presence of GM maize pollen his product was now unsuitable for marketing or consumption. The Bavarian Higher Administrative Court sought the European Court of Justice's (ECJ) advice on whether the mere presence of GM pollen required authorization so as to be placed on the market (Bird et al., 2013).

On September 6th 2011, the ECJ ruled that honey and food supplements containing GM pollen constitute foodstuffs which contain ingredients produced from GMOs (ECJ, 2011). Honey and food supplements are now classified under the (EC) 1829/2003 regulation on Genetically Modified Food and Feed. In its paragraph number 11 this regulation specifies that:

> "…authorization may be granted either to a GMO to be used as a source material for production of food or feed and products for food and/or feed use which contain, consist of or are produced from it, or to foods or feed produced from a GMO."

The ECJ ruling applies to honey produced within and outside the EU. Currently the EU allows honey to be imported from 'third countries' that cultivate GM crops, amongst the 82 'third countries' authorized to export honey to EU, 41 currently have EU approved residue monitoring plans in place for honey (Bird et al., 2013). Table 3.7 shows the countries in the Americas who cultivate GM crops and are authorized to export their honey to the EU.

Table 3.7. Countries Authorized to export honey to the EU that Cultivate GM Crops

Country	Genetically Modified Crops
Argentina	Soybean, Maize, Cotton
Brazil	Soybean, Maize, Cotton
Canada	Canola, Maize, Soybean, Sugar Beet
Chile	Maize, Soybean, Canola
Cuba	Maize
Mexico	Cotton, Soybean
United States	Maize, Soybean, Cotton, Canola, Sugar Beet, Alfalfa, Papaya, Squash
Uruguay	Soybean, Maize

Source: Commission Decision 2011/163/EU (2013)

Note: GM crops authorized for cultivation in these countries (James, 2014).

All the countries (with the exception of Cuba and Chile) in the table above are considered 'mega-countries', that is, they are growing 50,000 hectares or more of biotech crops. El Salvador is roughly five times smaller than the smallest country in the table above (Cuba). The countries in the table above could potentially have segregation between the areas where honey is produced and GM crops cultivated due to their size. However, this does not appear to be a criteria the EU contemplates when establishing EU approved residue monitoring plans for imported honey. That is, the mere cultivation of a GM crop obligates a desirous exporter of honey to the EU to seek a residue monitoring program. The costs of establishing and maintain a pollen residue program can be expected to fall on Salvadoran honey producers.

Furthermore, El Salvador and the EU are both members of the CPB and WTO. If a trade dispute were to arise due to GM pollen being detected in honey exported to the EU, it is not clear which agreement should take precedence (Kerr et al., 2014). This is an important issue because some views and rules embedded in the CPB are in sharp contrast to those embedded in the WTO. The CPB supports a *process-based* approach in contrast to the WTO which supports a *product-based* approach. Under the CPB, products of biotechnology especially, are treated in a similar way to waste. This is because the government of an importing country needs to be notified of the transboundary movement of a GMO, thus, the CPB also increases the role of government in trade. The WTO in contrast, attempts to remove or at least minimize the role of government in trade activities. Even the three dimensions which seem to be in concert between the two regulatory frameworks (supporting of a risk analysis framework, the precautionary principle and legitimate factors beyond science in regulatory decision-making), do not standup to scrutiny, that is, they are only similar superficially (Isaac and Kerr, 2007). Asynchronous approvals of GM crops make the conflicting rules between the CPB and WTO a contentious issue which is subject of an ongoing debate, without a clear guideline with which to proceed.

3.7. Summary

Table 3.8 summarizes the data incorporated into the economic surplus model used in this study to project the welfare and distribution effects among maize farmers, consumers and the gene developer. Two scenarios were simulated, one in which the government abandons the subsidy to maize producers (Scenario 1) and one in which it maintains the subsidy (Scenario 2). In Scenario 1 producers assume the cost of seed thus their surplus is reduced by the cost of the seed. In Scenario 2 the government assumes the cost of seed thus producer surplus should increase.

Table 3.8. Assumptions of Parameters Used		
Parameter	**Scenario 1**	**Scenario 2**
Equilibrium Price (P_t)	255	255
GM IR Maize Seed Price ($P_{GM\ IR}$)	130	130
Equilibrium Quantity Metric Ton (Q_t)	700,896	700,896
Current Yield (MT/ha)	2	2
% Yield Increase	18	18
% Cost Reduction	9	24
Supply Elasticity (ε)	0.22	0.22
Demand Elasticity, absolute value (η)	0.12	0.12
Initial Adoption Level (%)	30	52
Maximum Adoption Level (%)	90	90
Lag to maximum Adoption Level (years)	10	10

To measure the welfare and distribution effects of GM IR maize adoption, the methodology suggested by Alston et al. (1995) and Moschini et al. (2000) is employed. The values assigned to the parameters of the model are all taken from either field trials conducted by CENTA or other official sources of information. The ramifications of transgenic maize adoption are explored in depth. The trade agreements that are likely to be impacted by the commercial adoption of transgenic maize are presented and detailed. Results from the methodology are presented and discussed in Chapter 4.

Chapter 4. Results and Discussion

4. Introduction

The previous chapter discussed the methodology and the value of model parameters used to project the welfare and distribution effects from the hypothetical adoption of GM IR maize in El Salvador. First the potential adoption paths are stated. Then the change in economic surplus estimates are shown in Table 4.2 and Table 4.3. Sensitivity analysis on three key parameters is conducted in the following section. CAFTA-DR is then analyzed and its negligible influence on Salvadoran maize prices explained. Finally, the Salvadoran honey industry is discussed in detail.

4.1. Results

4.1.1. Genetically Modified Insect Resistant Maize Adoption

Table 4.1 presents the potential adoption paths for GM IR maize in El Salvador. Adoption paths depend on a variety of factors such as knowledge of the technology and its potential benefits or the technology's profitability. The assumption for El Salvador was that information of technology is disseminated and adoption of the technology occurs successfully. That is, maize farmers and domestic maize consumers accept the technology.

Table 4.1.Potential Adoption Paths for GM IR Maize (percent adoption per year)

Year	Scenario 1 (Without Subsidy)	Scenario 2 (With Subsidy)
2016	30	52
2017	38	55
2018	46	59
2019	55	63
2020	64	68
2021	71	72
2022	78	77
2023	83	82
2024	88	86
2025	91	91

Note: These paths are elicited with the formula: $\boldsymbol{A_t = A^{MAX} / 1 + e^{-(-\alpha + \beta_t)}}$

In Scenario 2, though initial adoption with the subsidy is significantly higher (22% more), by the sixth year of the technology's licensing, percent adoption is the same in either scenario. These were the adoption paths that were incorporated into the model of GM IR maize adoption in El Salvador.

4.1.2. Scenario 1

The first scenario for which results are presented is the one in which the government discontinues the 'agricultural packages' subsidy and farmers must assume the new higher seed cost (Table 4.2). This means that farmers receive an overall benefit of a 9% reduction in production costs per hectare. On average the NPV of the ΔTS for the ten-year projection of the hybrid is $848.5 million, of which $274.5 million accrues to domestic maize producers, $503.2 million to domestic consumers and $70.8 million to the innovator. Since maize is consumed locally, of total surplus increase generated by the technology, 92% remains in El Salvador and 8% accrues to the innovator.

Table 4.2.Economic Surplus of GM IR Maize Adoption (annuities thousands USD)

Year	ΔTS	ΔCS	ΔPS	π
2016	59,003	31,430	17,143	10,430
2017	74,506	39,706	21,658	13,142
2018	91,443	48,757	26,595	16,091
2019	108,891	58,091	31,686	19,114
2020	125,814	67,153	36,629	22,032
2021	141,293	75,449	41,154	24,690
2022	154,710	82,646	45,080	26,984
2023	165,808	88,603	48,329	28,876
2024	174,640	93,346	50,916	30,378
2025	181,453	97,006	52,913	31,534
NPV	**848,482**	**503,206**	**274,476**	**70,800**

The surplus of all economic agents (consumers, producers, and the innovator) increases with greater adoption, comparable to what is observed in other countries. However, by assuming that consumer and producer prices are the same and would change equally, transportation and handling costs are overlooked. It must be noted that consumer prices are actually much higher than farm-gate (farmer) prices, because some of the benefit is captured by intermediaries. Such a detailed analysis is beyond the scope of this thesis. Thus, this study may have overstated consumer surplus from GM IR maize adoption. The more plausible possibility is that the proportional consumer price decrease due GM IR maize adoption will be lower than farmer price decreases. This is because some of the benefit will likely be captured by intermediaries. This clarification aside, the distribution of benefits is comparable to what is observed for other GM crops destined for human consumption.

Although there is a plethora of studies assessing the economic impacts of GM crops. This study's results were juxtaposed with the results of other studies assessing GM crops employed for human consumption. Alston et al. (2002) found that had the US adopted a corn rootworm resistant transgenic maize variety in 2000, a total of $402 million of benefits would have accrued to farmers that year. Benefits to farmers in El Salvador are considerably lower than those prospectively modeled for farmers in the US for a single year. This is most likely due to the radical difference in productive capacity with respect to a developed country, thus studies with closer related socio-economic aspects were consulted. Napasintuwong and Traxler (2009) find that the producer benefit from adopting virus resistant papaya in Thailand is half than the benefit to consumers. This is due to the relation of elasticities. The elasticity of supply for papaya used in that study is 0.8 and the elasticity of demand is -0.4. In this study the elasticity of supply is 0.22 and the elasticity of demand is -0.12. The benefit to consumers in El Salvador is nearly twice that of that to producers due to the relationship of the elasticities, in congruence to what Napasintuwong and Traxler (2009) determined in Thailand. Krishna and Qaim (2008) find that even at the lowest adoption level (2%) eggplant farmers in India gain almost 25% less than consumers because of the elasticity relationship ($\boldsymbol{\varepsilon}$ = 1 and $\boldsymbol{\eta}$= -0.25).

4.1.3. Scenario 2

The second scenario for which results are presented is one in which the government continues the 'agricultural packages' subsidy to maize farmers, thus absorbing the cost of transgenic seed (Table 4.3). This means that farmers receive an overall benefit of a 24% reduction in production costs per hectare. This is because aside from GM IR maize seed, farmers would also receive 100 lbs. of ammonium sulfate fertilizer the unitary cost of which is $18.95 according to the Salvadoran maize cost structure (Table 3.3). The average NPV of the ΔTS for the ten-year projection for this scenario is $1,076.4 million, of which $352 million accrues to domestic maize producers, $645.3 million to domestic consumers and $79.1 million to the innovator. As in the first scenario, of total surplus increase generated by the technology, 93% remains in El Salvador and 7% accrues to the innovator. Innovator surplus is still estimated because the government currently buys the seed from private seed providers. This scenario implies that the government simply changes supplier of hybrid maize seed and assumes a new seed cost.

Table 4.3. Economic Surplus of GM IR Maize Adoption (annuities thousands USD)				
Year	***ΔTS***	***ΔCS***	***ΔPS***	***π***
2016	103,728	62,148	33,899	7,681
2017	111,547	66,840	36,458	8,248
2018	119,744	71,760	39,142	8,842
2019	128,307	76,901	41,946	9,460
2020	137,218	82,252	44,865	10,101
2021	146,456	87,800	47,891	10,764
2022	155,992	93,530	51,016	11,447
2023	165,796	99,421	54,230	12,146
2024	175,832	105,453	57,520	12,859
2025	186,059	111,602	60,874	13,583
NPV	**1,076,410**	**645,287**	**351,975**	**79,148**

Trigo (2011) found that GM IR maize generated $5.38 billion in gross total benefits between 1998 and 2010 to the Argentine economy. Of total surplus generated, 79.4% remained in Argentina while 19% accrued to GM seed provider. This is comparable to what is observed in El Salvador. That is, the vast majority of surplus generated remains in the country (92 or 93 per cent depending on the scenario). But perhaps the most remarkable aspect of the Argentine experience is that in 1998 113,738 ha were sown with GM IR maize. By 2010, a total of 3.2 million hectares were sown with GM IR maize seed. In just over a decade, there was a 28-fold increase in area sown with GM IR maize seed. Results obtained for El Salvador are considerably lower because the area (266,822 ha) is substantially lower. Thus, to further contextualize the results obtained in this study, studies with more relatable conditions are explored.

Demont and Tollens (2004) found that between 1998 and 2003, the aggregated producer surplus from GM IR maize adoption in Spain was 10.3 million euros. The GM seed industry extracted an aggregated gross profit of 5.2 million euros over that same period. Of total surplus generated by GM IR maize, farmers gained two-thirds (64.5%) of it, while one-third (35.5%) accrued to the seed industry. It is important to note that in that study, the area contemplated was only 25,000 ha, which may explain the low benefit generated. Furthermore, GM crops have greater yield and income effects in developing countries (Klümper and Qaim, 2014), which may explain the difference in magnitude of results found in El Salvador and those found in Argentina and Spain.

Not all GM crop adoption cases have been a success though. Afidchao et al. (2014) find that in Isabela province in the Philippines, there is no significant difference in net income between GM and non GM maize varieties. This however, is not due to pest abatement provided by GM IR maize, but actually due to the price of seed and technical inefficiency. Filipino maize farmers face a financial constraint because of high seed costs in combination with an expensive credit system in which they may pay 7 to 15 per cent interest to finance their inputs. Moreover, despite the use GM IR maize, farmers continued to spray pesticides on their maize crop. This essentially renders the use of a hybrid with pest abatement capacity ineffectual and thus, needlessly increases production costs. Gouse et al. (2005) were the first to describe a similar situation and termed it "technological triumph but institutional failure". In their case, GM IR cotton indeed increased yield and decreased pesticide use, which in turn improved income and lowered costs more than enough to offset higher seed costs. However, the lack of access to credit led to a drastic decline of cotton production. This study may serve as an example to Salvadoran authorities should they decide to license GM IR maize. Institutional issues such as the lack of access to credit, inputs and information on the correct management of the technology may limit producer interest in the technology.

4.2. Sensitivity Analysis

To assess the robustness of the results discussed this far, sensitivity analysis is undertaken. Special attention is given to three key parameters: transgenic seed price and supply and demand elasticities.

4.2.1. Innovator Surplus

The sensitivity of the results to the price of the seed is examined by decreasing the price from the original price of \$130 to \$100 per bag of 60,000 seeds. The resulting aggregate gross innovator surplus in Scenario 1 is reduced to \$32.7 million and in Scenario 2 is reduced to \$36.6 million. The difference between both scenarios is the celerity with which adoption takes place. In Scenario 1 initial adoption is 30%. Whereas, in Scenario 2 initial adoption is 52%. Not surprisingly, by decreasing seed price, gross innovator surplus decreases. Total surplus also decreases to \$810.4 million in Scenario 1 and to \$1,033 million in Scenario 2.

4.2.2. Price Elasticity of Supply and Demand

Alston et al. (1995) suggest that the elasticity assumptions are important in relation to distribution of benefits. Thus, to assess the robustness of results obtained, the distribution of ***CS*** and ***PS*** was determined under different values for the elasticities. The values FAPRI suggests for Latin America were used. With a value of 0.1 for supply and -0.2 for demand, the ***ΔCS*** and ***ΔPS*** was recalculated for both scenarios *ceteris paribus*. Changes were substantial and the role as to the economic agent who benefits the most from GM IR maize adoption was reversed. In Scenario 1, farmers gain $1.1 billion and consumers gain $554 million, or half as much. In Scenario 2, maize farmers gain $1.3 billion and consumers gain $664 million, once again half as much. The more elastic demand is relative to supply (or vice versa) the greater the producer share of total benefits and vice versa. These results are comparable to what Krishna and Qaim (2008) and Napasintuwong and Traxler (2009) observe, in both studies the elasticity of supply is more elastic relative to demand, thus, the consumer share of benefits is greater than the producer share.

4.3. Trade Considerations

4.3.1. Dominican Republic-Central American Free Trade Agreement

The high importance of maize to the Salvadoran economy explains the high degree of protection the crop received in the CAFTA-DR negotiations. A TRQ that expands gradually by 2% annually the first 15 years and from then on by 700 MT annually into perpetuity was negotiated (USTR, 2015). Whether the adoption of GM IR maize takes place or not, in 2025 Salvadoran imports of white maize within CAFTA-DR will be 48,300 MT. If total production were to remain at the 19-year average of 700,896 MT, amount of maize imported will only account for seven percent of national production. However, this is unlikely to happen should GM IR maize be adopted, that is, total production will likely increase thus decreasing the percentage CAFTA-DR imports represent. For the consideration period (ten years), which begins in 2016 and ends in 2025, CAFTA-DR imports will have a minimal effect. To further add validity to this statement, the behavior of domestic maize price since 2006 (when CAFTA-DR came into effect) until 2014 (most recent price) is seen in Table 4.4.

Table 4.4. Price per metric ton of maize since CAFTA-DR came into effect	
Year	**Price/MT (USD)**
2007*	241
2008*	243
2009	318
2010	296
2011	517
2012	339
2013	292
2014	339

Source: MAG (2015).
Notes: Interpolation is done for the years 2007 and 2008.

No perceivable reduction in price can be observed within the first eight years of CAFTA-DR coming into effect. Of course, eventually maize imports will have a perceivable economic impact on the Salvadoran maize sector. However, thus far and throughout the consideration period (ten years), the impact will be small enough that it can be disregarded. It is also important to note that should GM IR maize decrease price sufficiently, a state of autarky might be reached. That is, no imports of maize from the US would occur at that point.

4.3.2. Honey Exports to the European Union

The principal importers of Salvadoran honey are shown Figure 4.1. Indisputably Germany is the principal destination of Salvadoran honey. In 2015, honey exports to this country amounted to $6 million. Though total honey exports have tended to increase over the last 14 years, average exports over that same period amount to $4.2 million. If GM IR maize adoption occurs and subsequently the EU requires Salvadoran honey exporters to seek a monitored residue program, it can be expected that production costs could rise (Bird et al., 2013).

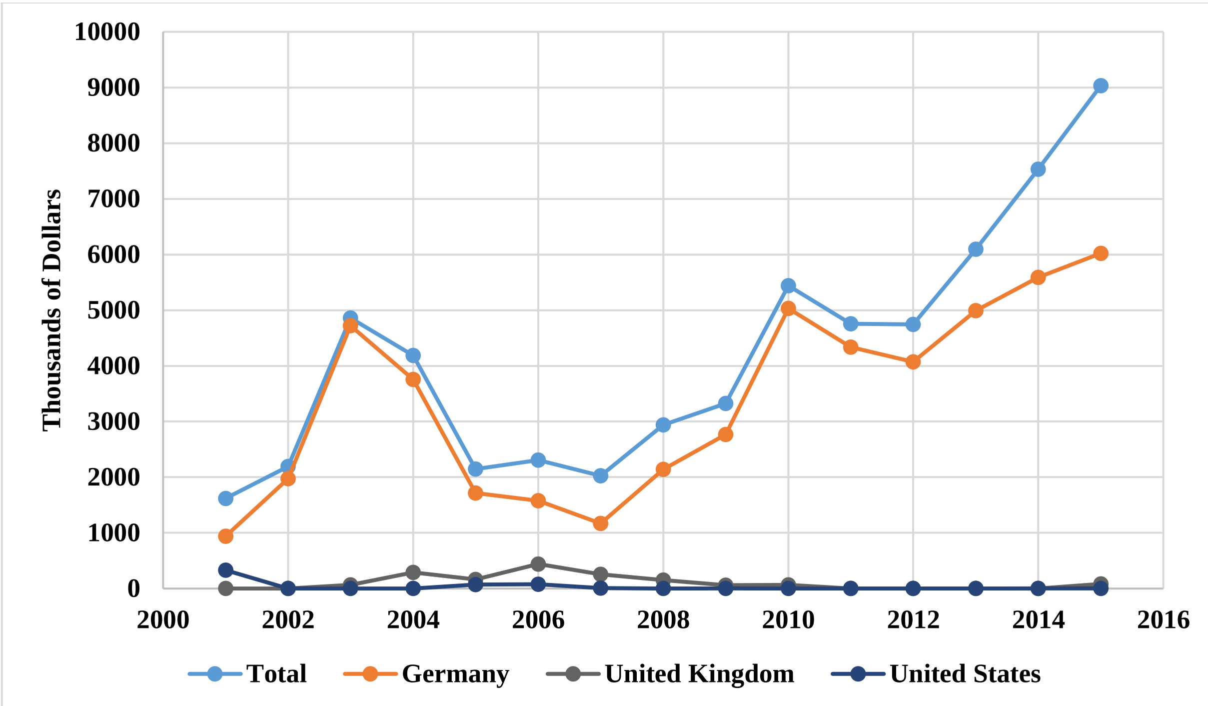

Figure 4.1.Destination of Salvadoran Honey

Source: Based on data from UN Comtrade Database

If Salvadoran honey producers are unwilling to navigate the legal framework and assume higher production costs (due to labeling requirements) in order to establish a residue monitoring program. This does not necessarily mean the end for Salvadoran honey exports. There are still eight other FTAs that Salvadoran honey producers could turn to (Table 4.5). These markets may not be as appealing to honey producers, but if the government were to allow the commercial use of GM IR maize it may invoke the *compensation principle*. Honey is worth $4.2 million to the Salvadoran economy and maize is a staple food currently worth $399 million. There is a strong possibility that maize would take priority.

Table 4.5. Honey Clause Under Distinct Free Trade Agreements El Salvador is Part of			
Name of Agreement	**Tariff (%)**	**Name of Product**	**Date Became Effective**
North Triangle-Mexico FTA	15	Natural Honey	March 15, 2001
El Salvador, Guatemala, Honduras-Colombia Free Trade Agreement	20	Natural Honey	February 1, 2010
Central American-Dominican Republic FTA	0	Natural Honey	October 4, 2001
Central American-Panama FTA	-	Natural Honey	April 11, 2003
CAFTA-DR	1.9 Cents/Kg	Natural Honey	March 1, 2006
Central America-Chile FTA	0	Natural Honey	June 03, 2002
El Salvador and Honduras-Republic of China (Taiwan)	15	Natural Honey	March 1, 2008
Central America	0	Natural Honey	-

Source: Author based on information from MINEC (2016).

4.4. Summary

GM IR maize adoption increases the surplus of all economic agents involved in maize production. However, the scenario that increases total surplus the most is the one in which the government maintains the subsidy to maize farmers. Even after conducting sensitivity analysis, domestic consumers and maize farmers are the economic agents who benefit the most from GM IR maize adoption. Until 2025, the effects of CAFTA-DR on the Salvadoran maize market will remain minimal. As for the trade aspect of EU-CA association agreement, it will be up to Salvadoran authorities to decide if GM IR provides sufficient benefit so as to justify a disruption to honey trade. If they decide to move forward with transgenic maize licensing, there are eight other FTAs that Salvadoran honey producers could turn to. Final comments are presented in the next section.

Chapter 5. Conclusion

As established in the first chapter of this thesis, maize production and enhancement of maize productivity are priorities of Salvadoran authorities. In the process of exploring technologies that could aid farmers, Salvadoran authorities evaluated GM IR maize. Field trial data showed that no insecticide use is necessary when cultivating GM IR maize in El Salvador. These hybrids can on average increase yield per hectare by 18% (and potentially by a greater percentage). The economic impact assessment these hybrids could have on the Salvadoran agricultural sector is of growing interest to policy makers. The potential economic impacts from licensing a GM IR maize hybrid for commercial cultivation was the primary focus of this study. To recall, the specific objectives of this thesis were to:

(1) Measure and report the **change in economic surplus** from the adoption of GM IR maize evaluated in the fields trials undertaken in the country.
(2) Disaggregate and determine the **distribution of this surplus** among the relevant economic agents (farmers, consumers, and the owner of the intellectual property rights to the technology). This will answer the question: who stands to gain the most from adopting GM IR maize in El Salvador?
(3) Identify the **implications for trade**, **if any**, from the adoption of GM IR maize.
(4) Determine and economically **assess any potential externalities** that may arise from adoption of GM IR maize.

5.1. Change in Economic Surplus and Distribution Effects

GM crops can be economically assessed by a variety of approaches. That is why in Chapter 2 an alternate approach to the one employed in this thesis was explored. Real option value models were explored and an example was discussed (evaluating GM wheat). However, that approach is complex and requires advanced knowledge of statistics, finance and economics. Explaining this methodology to policy makers and other technocrats would be very difficult. That is why the economic surplus approach was used in this study. This approach has been widely used in the literature to assess the impacts of technology adoption, both in *ex-ante* and *ex-post* settings, making it among the most familiar. Practicality of implementation also played an important role in the choice of approach. With relatively easily attainable data, field trial results and appropriate assumptions to account for practical farmer conditions, this approach trumped the use of real option value models. Economic surplus generated by introducing a transgenic maize variety was measured by using a system of equations. A logistic equation was employed to elicit adoption paths of transgenic maize. Conclusions may be easily drawn from the results obtained.

If El Salvador successfully licenses GM IR maize, the majority of economic benefits would accrue to consumers. This is because of the closed-economy assumption (for both scenarios) and the inelastic consumer demand for maize. Though by the welfare measure producers do not gain as much as consumers, they do have much to gain from the adoption of GM IR maize. Producers can expect a higher maize yield and less on farm time because spraying pesticides is not needed when employing GM IR maize in El Salvador. Regardless of whether the Salvadoran government continues the subsidy to maize farmers or not, the transgenic seed must be paid for every year. Thus, innovator rents were accounted for in either scenario in this study. The innovator supplying GM IR maize hybrid seed gains substantially lower than producers and consumers in either scenario. Based on the data used, assumptions made and that were subsequently made, Salvadoran maize consumers and producers gain the most from GM IR maize adoption.

5.2. Implications for Trade

Trade was initially hypothesized to be a potentially limiting factor in the licensing decision of transgenic maize. That is, the economic loss El Salvador could suffer from losing foreign markets by adopting GM IR maize would be great enough to dissuade Salvadoran authorities from the adopting this technology. However, an in depth exploration of trade ramifications proved this not to be the case. That is, CAFTA-DR maize imports during the next decade will be small enough that a closed-economy was able to be assumed. As for honey exports, should the German honey market become unavailable to Salvadoran honey producers, there are at least eight other markets with preferential treatment Salvadoran honey producers could turn to. This is perhaps not the most ideal situation for honey producers, however, it is safe to assume maize production takes priority on the Salvadoran development agenda. After all, field trials with a controversial technology were conducted with the specific objective of aiding this sector. Ultimately though, the decision to license this technology relies on policy makers.

5.3. Policy Implications

The objective of agronomically evaluating GM maize varieties was to ultimately verify if these could aid Salvadoran maize farmers should they be commercially licensed. Agronomically and economically there seems to be potential benefit from the adoption of this technology to both farmers and the Salvadoran economy (not accounting for effects in the input market). Furthermore, there is no reason to believe farmers who do not participate in the market (i.e. grow maize solely for subsistence) are worse off from the adoption of a transgenic variety. As for the government, policy makers will have to consider whether the subsidy program can be maintained with an expected increase in seed price (from $74.16 to $130 per hectare). Consumer acceptance of the technology and the food derived there from, remains a dubious matter. Should commercial adoption of GM maize take place, Salvadoran policy makers will undoubtedly have to navigate a context with potential winners and potential losers from this policy change. How they go about doing this remains uncertain because the strength of local institutions will be tested as adoption increases. Whether producers are helped or the government cedes to a typically clamorous group of consumers (as observed in other countries), remains to be seen.

5.4. Final Considerations

An issue that was not explored in this study but is of immense importance therefore is consumer or farmer opposition to this technology. Since field trials were undertaken, seven years have passed, and in that time the debate has generated highly polarized opinions. This polarized view could potentially alter adoption path of the technology and is an attractive area for further research. Two more areas emerged as appealing for potential further research. Given that field trials report no need for the spraying of pesticides should GM IR maize be cultivated, then the potential environmental and health benefits to farmers this entails should be explored. Furthermore, solely based on economic criteria, this economic impact assessment could compliment the environmental and social impact evaluation of GM technology in El Salvador.

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